NIRC2 Motor Control Programmer's Manual

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1 Overview

This document defines the software architecture for the NIRC2 instrument in regard to mechanisms other than the detector system.

This document should be reviewed by programmers prior to modifying the software or for an understanding of the underlying software.

1.1 Instrument description

The NIRC2 instrument is a near-infrared camera intended to provide high-resolution imaging in conjunction with the adaptive optics (AO) system on the Keck II telescope. The instrument will feature a Boeing 1024^2 Aladdin III InSb detector, providing diffraction-limited imaging in the J, H, and K pass bands (1-5 um range) with sensitivity between 5 and 10 times that of NIRC1. The instrument contains three plate scales, providing fields of view measuring 10, 20, and 40 arc seconds; these correspond to the diffraction limit for imaging at 1, 2, and 4 um, respectively. The instrument also provides coronagraphic imaging and diffraction limited spectroscopy over the 1-5 um range at R=5000.

The principal investigator is K. Matthews (Caltech) and the co-investigator is T. Soifer.

The detector electronics developed by the IR lab at UCLA are essentially identical to NIRSPEC. The detector readout is performed by a transputer system. The UCLA team also developed the software for the detector readout, and the associated user interface. This document does not address the UCLA software; that information is available in UCLA-generated documents.

1.2 Mechanisms

The instrument contains: eleven electro-mechanical mechanisms where the motors are external to the dewar; a single-stage and a dual-stage cold head; a Lakeshore temperature controller; a Lakeshore temperature monitor; and a controller for the calibration lamps.

The calibration lamps are on a stage on the AO bench, and the AO software and electronics move the selected lamp into position. The on/off control of the lamps is handled by a DGH digital I/O module and is interfaced by software described in this document.

Communication to all mechanisms is via serial I/O of one form or another. The mechanisms' serial links are connected to one of two terminal servers and the software, running on a UNIX host computer, interfaces to the mechanisms via the terminal server ports using TCP/IP.

The mechanisms are logically categorized as either motor controller mechanisms or I/O mechanisms, where a daemon task exists for each category as described in Sections 2 "Motor Daemon" and 3 "I/O Daemon." The interface to those daemon tasks is via a keyword library, which provides higher-level abstraction of the mechanisms such that clients are insulated from the communications details of each mechanism's command syntax and protocol.

1.2.1 Mechanism numbering

Information pertaining to each of the mechanisms is encoded in a set of configuration files that are read when the daemon tasks initialize (`nirc2_motor.config` and `nirc2_io.config`). There is also a configuration file, which is read by the keyword library pertaining to the mechanisms – `nirc2_mechanism.config`.

The mechanism configuration file specifies a unique number for each mechanism, which is referred to as the "major mechanism number." The motor and I/O configuration files, read by the daemon tasks, associate a "minor mechanism number" with each major mechanism number. The minor numbers are essentially the addresses to which a specific remote device will respond, thus, the minor numbers must be unique for a given communication link, but need not be unique across all devices/links. That is, each unique communication link may be connected to a device, which responds to an address of 1, for instance.

In most cases clients need not know any of the mechanism numbers. However, if a user wishes to bypass the keyword library and to interface to the daemon tasks via the support programs, they must be aware of major mechanism numbers. And, they must understand that the daemon tasks will convert the user-supplied major mechanism numbers to minor mechanism numbers when communicating with the remote devices (refer to Sections 2.4 and 3.4 "Support programs").

1.2.2 Motor-controlled mechanisms

The motor-driven mechanisms use Animatics Smartmotors that have their controllers and incremental encoders integrated with the motors. The motors' serial interface is RS-485, which provides for interconnecting the motors in a star configuration. Ten of the motors are connected in a star configuration with the pupil mask rotator being independently connected. The motor commands are all ASCII strings without any binary protocol or checksum. The motor addresses, however, are not ASCII printable characters (refer to the *Animatics User Manual*).

One of the motor-driven mechanisms is the shutter.

Six of the motor-driven mechanisms are essentially linear translation stages, referred to in this document as "sliders." The slider mechanisms are the camera selector, grism, slit, slit mask, inner preslit, and outer preslit. For the purposes of mechanism-control software, the shutter is also classified as a slider.

Three of the motor-driven mechanisms are rotational mechanisms (wheels), which are typically driven to discrete locations so as to place specific filters and such in the light path. The "wheel" mechanisms are the inner filter wheel, outer filter wheel, and the pupil mask selector.

The remaining motor-driven mechanism is the pupil mask rotator that rotates in a tracking mode following the telescope elevation angle and the AO image rotator. The software used to drive this mechanism is considerably different from that which drives the other motor-controlled mechanisms; the differences are thoroughly covered in subsections of this document.

All of the motor-driven mechanisms, with the exception of the shutter, have a homing switch and two ends of travel switches.

1.2.3 Thermal mechanisms

As previously mentioned, the thermal mechanisms are a single-stage cold head, dual-stage cold head, temperature controller and temperature monitor.

Embedded within the cold head control electronics are various DGH analog and digital modules. The host control software communicates with the DGH modules via RS-232 serial links, which are connected to terminal server ports.

The Lakeshore temperature controller and monitor also have RS-232 serial links connected to terminal server ports.

All of the thermal mechanisms have ASCII string command sets without any protocol or checksum.

1.2.4 Calibration lamps

The calibration lamps' power is controlled with the instrument software via a DGH digital output module, which is connected to a terminal server port. The lamps are physically mounted on a stage on the AO bench. The lamp positions are controlled by the AO software and electronics.

1.3 Software architecture

Software to control the aforementioned mechanisms has been subdivided into four main components, each of which is discussed in detail in this document.

The four main software components are:

1. a body of software referred to as the "motor daemon" whose interface is via remote procedure calls (RPC) and whose function is to act as the communications interface to the motors;

2. a body of software referred to as the "I/O daemon" whose interface is also RPC and whose function is to act as the communications interface to the non-motor devices;

3. a keyword library which provides a higher level interface to the daemons via the Keck tasking library (KTL); and

4. the pupil mask rotator (PMR) control software which is distinct from the keyword library and motor daemon.

2 Motor Daemon

Interface to the NIRC2 motors is via a body of software referred to as the motor daemon. The motor daemon is responsible for converting motor demands and requests into syntactically correct motor-specific commands (Animatics language). Note that only subsets of the Animatics commands are encoded in the motor daemon and, therefore, a finite set of possible calls exist. The implemented calls are enumerated in subsequent subsections.

The motor daemon is a standalone task, which is intended to be executed when the NIRC2 control system host is booted.

Communication with the motor daemon is via a set of RPCs, which are enumerated in subsequent subsections.

The normal mechanism for interfacing with the motor daemon is via the KTL. This includes user command line use of "`show`," "`xshow`," and "`modify`," as well as scripts and client programs. However, it is possible to create client programs that bypass the keyword layer and directly communicate with the motor daemon via RPC calls. Such is the case of the standalone programs such as `tellmotor` and `askmotor` (refer to Section 2.4 "Support programs").

For each motor type supported by the motor daemon, a motor-specific module must exist, hopefully, in an appropriately named subdirectory. As of November 2000, the motor daemon supports Animatics Smartmotor controllers and hooks have been added for Compumotor (utilized in generation 1 Keck IR instruments) and API (used in SHARC and OSIRIS). During startup configuration files are read and parsed. Some of the parsing is handled by functions in the motor-specific module `animatics.c`.

Irrespective of the underlying motor type, all keyword library interactions with the motor daemon are via a set of RPC functions, which are intended to be device-independent. In most cases, the RPC functions ultimately call functions in the motor-specific modules. The motor-specific modules' functions are not addressed herein. However, the RPC functions are discussed in the following subsections.

2.1 RPC functions

As previously mentioned, the interface to the motor daemon is via a set of RPC functions. The intent is that the keyword software and/or client programs need not know any of the underlying motor-specific commands/language but, rather, that certain motor functions are supported. The keyword library translates the mechanism and motor keywords into the appropriate RPC calls to the motor daemon, thus the following information is provided for the requirements imposed on any new client programs.

Rather than creating a specific RPC function for every possible motor function, or subset thereof, the motor functions were grouped into two main classes, which are handled by two distinct RPC functions, and six other special purpose RPC functions.

The two main classes are motor commands and motor requests, which are respectively handled by `motorcmd_1()` and `motorsts_1()`. The six special purpose RPC functions are `tellmotor_1(), askmotor_1(), setmotorprop_1(), getmotorprop_1(), findmotor_1()`, and `motorinfo_1()`.

In the following subsections there are frequent references to "client." One client is the keyword library itself, which uses most, if not all, of the RPC functions. However, the keyword library is not, and need not be, the only client. For instance the motor daemon support programs (refer to Section 2.4 "Support programs") are also clients.

2.1.1 Data structures

The nature of an RPC interface is such that each RPC function takes a pointer to an argument, which may be a scalar or a structure, and returns a pointer to a scalar or structure. It is the calling program's responsibility to free the memory for the returned item.

The data structures for the motor daemon RPC functions are `mtrInfo(), mtrMsg(), mtrProp(), mtrStrReply()`, and `mtrReply()`, which are defined in `motor.h` and derived from `motor.x`.

Note that the data structures returned from RPC calls must be explicitly deallocated with `xdr_free()`. If this were not done a memory leak would exist.

2.1.1.1 MtrInfo

The `mtrInfo` structure is used in two of the motor daemon RPC calls (`motorcmd_1`, and `motorsts_1`). This structure allows a client to specify a `<motor, command, value>` tuple for affecting motor behavior.

The `mtrInfo` structure consists of three fields:

1. an integer field "`motor`," which must be set to the major-motor number (refer to Section 2.2.2 "Motor specifications") of the motor to be affected by the command;

2. another integer field "`code`," which is one of the enumeration `MOTOR_ CODES` defined in `controller.h` and discussed as needed in the RPC functions subsections; and

3. a float field "`value,`" which is the command-specific parameter for the motor.

2.1.1.2 MtrMsg

The `mtrMsg` structure is used in two of the motor daemon RPC calls (`tellmotor_1` and `askmotor_1`). This structure allows a client to send arbitrary command strings to a motor. The string is not parsed or interpreted in any way; hence, it is the client's responsibility to ensure the command string is valid with respect to the motor controller's command syntax.

The `mtrMsg` structure consists of two fields: an integer field "`motor`," which must be set to the major-motor number (refer to Section 2.2.2 "Motor specifications") of the motor to be affected by the command; and a character pointer (string) "`field msg`," which is the command string to be sent to the motor. Client programs must allocate the space for the string fields.

2.1.1.3 MtrProp

The `mtrProp` structure is used in the motor daemon's `setmotorprop_1` RPC call. This structure allows clients to store arbitrary `<name, value>` strings in a hash table within the motor daemon. The intent is to store values that a client would later retrieve for internal use. This concept is discussed in more detail in a subsection about "user variables" in the Keyword Library documentation (refer to Section 4.4 "User keywords").

The `mtrProp` structure consists of two character pointer fields (strings), namely, "`name`" and "`value`." The client must allocate the space for the strings.

2.1.1.4 MtrStrReply

The `mtrStrReply` structure is returned to a client in response to an `askmotor_1`, `getmotorprop_1`, or `motorinfo_1 RPC` call. All of these calls return string data to the client.

The `mtrStrReply` structure consists of a status field (a value of 1 means success), an error message string (typically set when the status is not 1), and a reply message string.

2.1.1.5 MtrReply

The `mtrReply` structure is returned to a client in response to RPC calls, which do not return a string. The structure only provides for scalar values.

The `mtrReply` structure consists of:

1. a status field which is set to 1 on success;
2. an error message string which is typically set when the status is not 1;
3. a flag field which indicates whether or not the value is returned as a double or integer value;
4. a long integer value field which is set to the return value if the integer flag field is set; and
5. a double real value field which is set to the return value if the integer flag field is not set.

Note that the integer flag field is controlled within the motor-specific protocol routine, which, in this case, is handled within `animatics.c`.

2.1.2 Motor command codes

When a client attempts a motor command or request, an RPC call is ultimately invoked. A set of C routines exists in `motor.c` to translate client calls into the relevant RPC calls. In most cases the RPC

call involves a `mtrMsg` structure (discussed above). Within that `mtrMsg` structure is a command code, which is interpreted by the motor-specific protocol routines within `animatics.c`. The valid command codes are hard coded as an enumeration within `controller.h`. Not all command codes are implemented within `animatics.c` (refer to Section 2.1.3 "Adding new motor command codes to support new motor operations" to extend the available Animatics functions).

The intent of the motor command codes is to separate motor operations from motor command specifics such that a generic set of motor operations can be derived. Which of those motor operations can be applied to a given motor type is then dependent upon the implementation within the motor-specific module included in the motor daemon; in the case of NIRC2 the module is `animatics.c`.

To paraphrase, a client should use the functions in `motor.c` to perform common motor operations as doing so will hide not only the motor specifics (command language) and RPC calls, but also the motor command codes needed to depict the operation.

The functions within `motor.c`, which implement the motor operations, are documented in the relevant subsections of the keyword library. However, the motor operations that are implemented for the NIRC2 Animatics motor controllers, and for which motor command codes exist in `controller.h`, are enumerated in the following list.

- **`Home a motor`** - this invokes a subroutine in the motor controller's non-volatile memory
- **`Return a motor's current homed state`** - the state is retained in a motor controller variable that is set at the end of controller's homing subroutine
- **`Return a motor's current idle status`** - a motor controller variable is set at the beginning of each of its subroutines and clear at the end of those subroutines
- **`Initialize a motor`** - this invokes a subroutine in the motor controller's non-volatile memory which set the controller's control dynamics to safe defaults
- **`Return a motor's current initialized state`** - the state is retained in a motor controller variable which is set at the end of its initialization subroutine
- **`Return a motor's current limit status`** - this used motor controller commands to determine the motor was last stopped due to an encounter with a travel limit
- **`Return a motor's current CCW software limit`** - this is a value cached in the motor daemon and is the largest negative encoder value that a client may specify in an absolute move command
- **`Return a motor's current CW software limit`** - this is a value cached in the motor daemon and is the largest positive encoder value that a client may specify in an absolute move command
- **`Return a motor's current control status`** - this is a composite of a motor's various travel limit and fault statuses which is assembled from the responses to several motor controller commands

- **Return a motor's motor type** - this is a numeric value that motor daemon associated with a given motor type
- **Return a motor's motor position in encoder counts**
- **Return a motor's current shutdown state**
- **Return a motor's current stall fault state**
- **Return a motor's current communications overflow fault state**
- **Return a motor's current over-temperature fault state**
- **Enable/disable echo mode** - one can instruct the Animatics Smartmotors to echo all commands they receive
- **Set a motor's acceleration value**
- **Set a motor's maximum current value**
- **Set a motor's maximum position error value**
- **Set a motor's maximum velocity**
- **Set a motor's backlash offset value** - this is retained in a motor controller variable and is the distance moved at the end of a motor move in order to accommodate for backlash
- **Set/release a motor's brakes** - this is typically not used during operations as brake control is automatically performed at the beginning and end of motor motions, but is provided as a troubleshooting and debugging function. Setting a motor's brakes reduces current flow and heat generation.
- **Enable/disable a motor's servo/power-on state** - this is typically not used during operations as brake control is automatically performed at the beginning and end of motor motions, but is provided as a troubleshooting and debugging function. Disabling a motor reduces current flow and heat generation.
- **Perform a software reset on a motor**
- **Decelerate a motor to a stop**
- **Abruptly stop a motor (kill)**
- **Move a motor to a specific encoder position** - this is an absolute move, which is accomplished via a subroutine in a motor controller's non-volatile memory. The subroutine handles brake control, power/servo control, and any backlash removal.
- **Move a motor relative to its current position** - this is a delta move, which is accomplished via a subroutine in a motor controller's non-volatile memory. The subroutine handles brake control, power/servo control, and any backlash removal.

- **`Invoke a special motion routine`** - this is a subroutine within the motor controller's non-volatile memory which is identified in `nirc2_motor.config` file on daemon startup (refer to Section 2.2 "Configuration file format")
- **`Set a motor's trace level`** - this is retained in the motor daemon and provides increasingly detailed feedback of the daemon's actions
- **`Return a motor's current trace level`**
- **`Set a motor's simulation level`** - when enabled, interaction with a motor does not occur, but a set of software simulation routines is invoked instead
- **`Return a motor's simulation level`**

2.1.3 Adding new motor command codes to support new motor operations

At some point in time it may be necessary to support additional motor operations, perhaps in response to new motor controller subroutines. To do so one would need to extend the motor code enumerations (motor codes in `controller.h`) and then add a case statement to one or both of `animaticsSts()` and `animaticsCmd()` within `animatics.c`.

2.2 Configuration file format (nirc2_motor.config)

When the motor daemon initializes, it reads and parses the records contained in a configuration file. The configuration file is specified in the default script, which is provided as a daemon command line argument. Throughout this manual the configuration file is referred to as `nirc2_motor.config`, however, it is possible to change this in the default script, which one may wish to do for testing and/or troubleshooting.

The motor configuration file has three functions:

1. to identify the communications links;
2. to identify the motors connected to a given link; and
3. to specify the motor characteristics of each of those motors.

More than one communications link may be specified, but all motors and their characteristics, for a given link, must be specified before another link is specified. That is, all motor information following a communications link is assumed to be relevant to the communications link, up to the point that another communications link is specified.

2.2.1 Communications link specifications

The purpose of the communications link specification is to identify the communications device to which one or more motor controllers are connected.

The motor controllers may be connected to a host (UNIX machine) serial port, in which case the syntax would be:

```
serial <port name>
```

Where the "`port name`" is the string as specified in the host's device table (e.g., /dev/term/b).

Alternatively, the motor controllers may be connected to a terminal server port, in which case the syntax would be:

```
ethernet <host id> <port number>
```

Where "`host id`" would be the terminal server name/IP address, and "`port number`" is the terminal server port to which the controller is connected (e.g., `ethernet nirc2_ts 3002`).

2.2.2 Motor specifications

For each motor connected to a communications link there must be a motor specification followed by several motor-characteristic specifications.

The syntax for the motor spec is:

```
motor=<motor type> <major-motor number> <minor-motor number>
{icd=<microseconds>}{rxd=<microseconds>}
```

Where:

The `motor type` is Animatics for NIRC2.

The "`major-motor number`" or instrument-wide number must be unique within this configuration file, and this motor number must correlate with the number specified for a given mechanism in the mechanism-configuration file (refer to Section 4.5.2 "Nirc2_mechanisms.config").

The "`minor-motor number`" is the motor address or number to which a specific motor controller will respond. This need not be unique as two motors on two different communication links may have the same motor address.

"`icd`" is an inter-character delay used when writing to the communications link. If "`icd`" is not specified then characters are output in bursts and fragmentation by the UNIX driver and/or terminal server may have an affect.

"`rxd`" is the receiver delay (typically 2 to 3 seconds), which specifies the maximum amount of time for which a reply will be awaited. If a reply takes longer than the receiver delay then an error will be logged.

2.2.3 Motor characteristics

Each motor possesses a set of characteristics, which can be specified in the motor configuration file. The characteristics and, consequently, the syntax for those characteristics is motor-type specific, therefore, the parsing of the characteristics is encoded in the motor-specific module, which, for NIRC2, is `animatics.c`.

The exact set of characteristics required depends upon the Animatics subroutines stored in the controllers.

Each characteristic must exist on a separate line in the configuration file where the syntax is:

```
<characteristic>={<value> | <command string>}
```

Note that a command string must be enclosed in double quotes.

In the case of a command string, the motor daemon always formats the motor address (refer to the *Animatics SmartMotor User's Manual*), and inserts it at the beginning of the string, prior to sending the command string to a motor controller. However, the Animatics Smartmotor firmware used in the NIRC2 controllers will always respond to commands that are not preceded by a motor address, thus, it is necessary to embed motor addresses in command strings when the command strings contain more than a single motor command. The syntax for embedded motor addresses – in fact, any non-printable ASCII value - is to specify the value as an octal value preceded by a "\" character. These backslash sequences are parsed/translated by the routines in `animatics.c` when the configuration file is read. As an example, the string "`\202Ra`" would specify a request for motor controller 2 to return the current value of its "`a`" variable.

A command string may also require that a value other than the motor number be embedded prior to sending the command string to a motor. For instance, a motor motion subroutine may need a variable set to the destination prior to being run. This is permitted by the use of "`%`," similar to the C `printf` statement, albeit only integer and single precision floats are needed. As an example, the string "`\202d=%d \202g=2 \202RUN`" would set motor controller 2's "`d`" variable to a user-specified value (this is actually the absolute move command string as "`g`" is used to specify which motor controller subroutine to run).

In general, entries exist in the motor configuration file for motor characteristics, which require an implementation-specific motor controller command string (perhaps to use a subroutine in the motor controller's non-volatile memory), or which utilize a motor controller variable, or which are parameters that may be dynamically changed.

The characteristics, which the functions in `animatics.c` will recognize, are discussed in the following subsections. Examples for each characteristic can be found in the operational configuration file `nirc2_motor.config`.

2.2.3.1 Resolution

The motor resolution specifies the number of encoder counts per motor shaft revolution. For NIRC2 the characteristic tag is "`resolution`" or "`motorres`" or "`mr`." In retrospect, this should probably have been hard-coded as a default such that an entry would exist in the configuration file if a different motor were ever substituted.

2.2.3.2 Negative software limit

The negative software limit is the smallest encoder position that a client is permitted to specify as a motor destination. If this value is exceeded then the motion command will be rejected and an error will be logged. For NIRC2 the characteristic tag is "`low_ml`" or "`low_motion_limit`" or "`negative_limit`" or "`neg_limit`" or "`min_position`" or "`min_posn`."

2.2.3.3 Positive software limit

The positive software limit is the largest encoder position that a client is permitted to specify as a motor destination. If this value is exceeded then the motion command will be rejected and an error will be logged. For NIRC2, the characteristic tag is "`high_ml`" or "`high_motion_limit`" or "`positive_limit`" or "`pos_limit`" or "`max_position`" or "`max_posn`."

2.2.3.4 Motor dynamics

The motor-control dynamics' parameters are assumed to be set within a motor controller's initialization subroutine. These values can be changed with the appropriate keywords (refer to the appropriate subsections in Sections 4.1.3 "Mechanism operations relating to keyword suffixes," 4.2.1 "Generic motor keywords," and 4.2.2 "Motor-specific keywords"). However, characteristic tags exist in the motor configuration file for a few of the values. The specified values are not used by the functions in `animatics.c` and exist so that the motor simulator can function close to reality, that is, the values in configuration file are fed back to functions in `animaticsSim.c` for when simulation is enabled for a motor (refer to Section 4.1.3.26 "SIM").

The characteristic tags are: "`acceleration`," "`accel`," or "`a`"; "`velocity`," "`vel`," or "`v`"; "`homing_velocity`," "`homing_vel`," "`homingvel`," or "`hv`"; "`position_error`," "`positionerr`," or "`pe`"; and "`backlash`" or "`bd`."

2.2.3.5 Backlash

A backlash correction has been programmed into the motion subroutines that are retained in the motor controllers' non-volatile memory. The values are retained in motor controller variables. Characteristic tags exist in the motor configuration file for the purpose of setting and reading back the backlash values. The characteristic tag for setting the backlash is "`backlashcmd`" and the tag for reading the current value is "`backlashrbv`."

2.2.3.6 Position error

The motor controller's subroutines use an internal variable for retaining the position error. This was done so that the value can be dynamically changed. Of course, this means that characteristic tags must exist in the motor configuration file for the purpose of setting and retrieving the values. The tag for setting the position error is "`posnerrcmd`" and the tag for the read back is "`posnerrrv`."

2.2.3.7 Brake control

The brake control specifies motor-control sequences that are needed to either set or release a motor's brakes. For NIRC2, the brakes are controlled by output latch A, which is controlled by the Animatics user output command "`UA`," such that "`UA=1`" sets a brake and "`UA=0`" releases a brake. Two sequences are needed so there are two characteristic tags, "`brakeon`" and "`brakeoff`."

2.2.3.8 Reset

The reset characteristic/keyword tag specifies the motor-control commands needed to cause a motor to perform its software reset. This was added as a characteristic so that a motor controller subroutine could be invoked, if necessary, but such a subroutine was not created for the NIRC2 mechanisms. Hence, this could have been eliminated from the configuration file by hard coding the reset command in the relevant function within `animatics.c`.

2.2.3.9 Initializing

The initialization characteristic also consists of three characteristic tags. The tag "`init`" specifies the command sequence required to initialize a motor, which basically sets the motor's control parameters to a safe default value as the parameters after a reset, or power cycle will not allow a motor to move.

The second characteristic tag is "`isinit,`" which specifies the motor controller commands needed to fetch the initialization state. The init subroutine sets a motor controller variable to 1 when initialization is complete, and it is this variable that indicates whether or not a motor has been initialized since the last reset or power cycle.

The third characteristic tag is "`isinitval,`" which specifies the value of the `isinit` characteristic, which indicates that initialization has been completed since the last reset or power cycle. The intent is to allow for negative logic.

2.2.3.10 Homing

The homing characteristic consists of three characteristic tags. One of them is "`home`" and specifies a command sequence for homing a motor. A subroutine exists in the motor controllers' non-volatile memories for homing.

Another characteristic tag – "`ishome`" – specifies the motor controller commands needed to fetch the homing status. The homing subroutine sets a motor controller variable to 1 when complete, and it is this variable that is identified as the `ishome` characteristic.

Lastly, the characteristic tag "`ishomeval`" specifies the value of the `ishome` characteristic, which indicates that homing has been completed since the last reset or power cycle of the motor in question.

2.2.3.11 Motor motion sequences

Motor controller subroutines exist in the motor controllers' non-volatile memories for moving the motors to absolute or relative positions. The subroutines are needed to automatically release and set brakes, enable and disable motor power, check for travel limit conditions, and to handle backlash. The motor configuration file tags for the motions are "`absmove`" and "`relmove`."

2.2.3.12 Idle status

No single Animatics command exists to determine whether or not a motor is actually in an idle state, so each of the motor controller subroutines that move a motor use a variable for this purpose. The variable is set at the beginning of those subroutines and cleared at the end. Hence, two characteristic tags exist for determining if a motor is idle, "`isidle`" is the command sequence to get the variable's value and "`isidleval`" specifies the value, which indicates that the motor is idle.

2.2.4 Adding new motor characteristics

It is feasible that at some point a new motor characteristic will be needed. Perhaps this would occur in response to a modification to one of the motor controller subroutines downloaded into the motor controllers' non-volatile memories.

To add a new motor characteristic one must determine the tags (strings) that will be used in the motor configuration file and then add an appropriate "else clause" to either `parseScalar()` or `parseString()` within `animatics.c`. `ParseScalar` is used when a simple numeric value is needed and `parseString` is used for sequences, which must be enclosed in double quotes within the configuration file. One may also need to update the data structure used to retain the information, if an appropriate unused field does not currently exist in that structure. The structure is "`animatics_details`" which is defined in `daemon.h`.

2.3 Logging and debugging

Motor daemon logging has been implemented with the UNIX facility `syslog`. The calls within the motor daemon are to `errlog(),` which actually performs the `syslog` calls, thereby providing some insulation from changes in the logging mechanism.

The syslog logging level can be controlled in two ways. First, logging can be controlled by setting the environment variable `LOG_UPTO` in the context within which the motor daemon is started. The values for this are provided by the lev_array within $KROOT/kss/ir_common/util/arg_functions.c (emerg, alert, crit, err, warning, notice, info, debug) where the higher priority logging levels are given first.

The second means of controlling the motor daemon's logging level is via a command line argument when the daemon is started. One must follow the parameter "`-log_upto`" by one of the previously mentioned levels.

Both of the aforementioned mechanisms for controlling the logging level are handled by the call to `setup_openlog()` within $KROOT/kss/ir_common/motor/daemon/mtrCalls.c.

Assuming the logging level is appropriately set (typically debug), then the amount of information logged by the motor daemon can be controlled dynamically via keywords.

Two motor-command codes (refer to Section 2.1.2 "Motor command codes") exist to control logging level for the purpose of debugging and/or obtaining additional motor daemon feedback. The intent is that instrument keywords would exist to control the logging level via the keyword library, namely, "`mtrmtrace`" and "`mtrdtrace`" (refer to Section 4.2.3.2 "MTRDTRACE and MTRMTRACE"). These keywords are controlled via the NIRC2 keyword library and are manipulated with "`show`" and "`modify`."

Setting `mtrdtrace` to some value greater than 0 will cause the motor daemon interface functions to log information for each function called. Setting `mtrmtrace` to some value greater than 0 will cause the functions within `animatics.c` to log information. In general, the higher the logging level the more detailed the log will be.

Setting `mtrmtrace` to 1 will cause the `animatics.c` I/O functions to log the exact strings that are transmitted and received to/from the motors. Setting `mtrmtrace` to a value greater than 2 will cause the transactions to be written to standard output.

Setting `mtrmtrace` to 2 will cause all function entries and exits to be logged.

Numerous messages may be logged. The messages are intended to be self-explanatory, so no attempt is made, herein, to describe the troubles, which would cause a given set of logged messages.

2.4 Support programs

Support programs exist for the purposes of troubleshooting, integration, and motor controller setup. The instrument specialists and/or the software support personnel (but not the user community) are expected to use these programs.

The support programs bypass the keyword library and interface directly to the motor daemon via the RPC interface.

The support programs are software modules written in the C programming language.

2.4.1 Tellmotor

`Tellmotor` is a standalone RPC client that allows one to issue a command string, to a specific motor controller, via the motor daemon.

To use `tellmotor` one must provide a motor number and a command string. The motor number is the instrument-wide number, as specified in `nirc2_mechanism.config` (refer to Section 4.5.2

"Nirc2_mechanisms.config (mechanism characteristics)"), and which is correlated to a motor address in `nirc2_motor.config` (refer to Section 2.2 "Configuration file format").

The command string should be one or more motor controller commands. If more than one command is entered on the line, then the entire command string must be enclosed in double quotes, not including the motor number. The command string is transmitted to the motor controller as entered, thus, the command string should be syntactically correct for the Animatics language including case. There are a couple of exceptions to this rule.

The command string will be preceded with the motor address, which is the equivalent of octal "`\200`" plus the motor number. Note the motor numbers are programmed into the controllers with a default of 0 when they arrive from the manufacturer.

Also one can enter non-printable ASCII value in C octal format and they will be translated into the appropriate 8-bit binary value. This allows one to enter the motor address in front of successive motor controller commands as `tellmotor` only inserts the motor address at the beginning of the entire command string (some Animatics controllers will respond to any command which is not preceded by a motor address, so be wary and, in general, use this technique).

An example, which would set the velocity for motor 1 to approximately 1 rev/sec:

```
tellmotor 1 V=32212
```

Another example to stop motor 2 and set its velocity:

```
tellmotor 2 "S V=32212"
```

or

```
tellmotor 2 "S \202V=32212"
```

If one enters a motor controller command to which the controller sends a response, `tellmotor` will not wait for that response (use `askmotor` instead) and that response will be flushed (discarded) with the next command issued on that communications link.

2.4.2 Askmotor

`Askmotor` is a standalone RPC client that allows one to issue a command string to a specific motor controller via the motor daemon, in response to which the motor controller will return some value.

To use `askmotor` one must provide a motor number and a command string. The motor number is the instrument-wide number, as specified in `nirc2_mechanism.config` (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)"), and which is correlated to a motor address in `nirc2_motor.config` (refer to Section 3.2 "Configuration file format").

The command string should be one or more motor controller commands. If more than one command is entered on the line, then the entire command string must be enclosed in double quotes, not including the motor number. The command string is transmitted to the motor controller as entered, thus, the command string should be syntactically correct for the Animatics language including case. There are a couple of exceptions to this rule.

The command string will be preceded with the motor address, which is the equivalent of octal "`\200`" plus the motor number. Note the motor numbers are programmed into the controllers with a default of 0 when they arrive from the manufacturer.

Also, one can enter non-printable ASCII value in C octal format and they will be translated into the appropriate 8-bit binary value. This allows one to enter the motor address in front of successive motor controller commands as `askmotor` only inserts the motor address at the beginning of the entire command string (some Animatics controllers will respond to any command that is not preceded by a motor address, so be wary and, in general, use this technique).

An example which would request the current absolute position of motor 1:

```
askmotor 1 RP
```

The controller response would be printed out.

Another example to stop motor 2 and request the position:

```
tellmotor 2 "S RP"
```

Note that one can include multiple status requests in a single command, but the daemon will only wait for a single response. All subsequent responses will be flushed (discarded) with the next command issued on that communications link.

2.4.3 Loadmotor

`Loadmotor` is a standalone program, which allows one to download a motor controller program into a motor controller or upload a program for a motor controller (for NIRC2 refer to the *Animatics SmartMotor User's Manual*). For each of the NIRC2 motors, a program consisting of at least the following subroutines exists: initialization, homing, absolute move, and relative move. The same program is not downloaded into all motors for the shutter behavior differs, as it has no travel limits, the pupil mask rotator provides for a tracking mode, and a few of the other mechanisms require different servo parameters.

The loadmotor program may be used as an RPC client of the motor daemon, or it may communicate directly over an ethernet port (terminal server), or a serial port.

The allowed syntax is:

```
loadmotor [UP | DOWN] daemon <motor address> <filename>
```

or

```
loadmotor [UP | DOWN] serial <port name> <motor address>
<filename>
```

or

```
loadmotor [UP | DOWN] ethernet <host> <port> <motor address>
<filename>
```

Where "`motor address`" is the instrument-wide number (major), as specified in `nirc2_mechanism.config` (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)"), and which is correlated to a minor motor number in `nirc2_motor.config` (refer to Section 2.2 "Configuration file format"). The "`motor address`" must be specified for ethernet and serial loads because the correlation between the major and minor numbers is known by the motor daemon and it is not involved in these cases.

The serial "`port name`" would be the host serial port name, on the UNIX system from which the program is executed and to which the motor controller is connected.

The ethernet "`host`" would be the terminal server IP address.

The ethernet "`port`" would be the terminal server port number to which the motor controller is connected.

The "`filename`" is the path and name of the file containing the program to be downloaded. The program must conform to that expected by the motor controller (for NIRC2 it is Animatics, so please refer to the *Animatics SmartMotor User's Manual*). Each line in the specified file is read and then transmitted to the motor controller with either `write()` (for serial and ethernet) or the `tellmotor_1` motor daemon RPC call.

The downloaded program is preceded by a "`SADDR`" command, which sets the controller's motor address as per that specified on the `loadmotor` command line. Once the download is complete, the motor controller will respond to all commands preceded by that motor address [be certain that two or more motors are not programmed with the same motor address for any group of motors that are multi-dropped on the same serial line (as is the case for 10 of the NIRC2 motors)].

If a download is via a terminal server then a special problem exists. The Animatics end-of-program terminator is the character with the octal equivalent of "`\377`." The terminal server intercepts this character and does not pass it through to the motor controller. Consequently, one must cycle power to the motor after the program has been downloaded to disable the controller's load mode (i.e., the controller waits for the end-of-program character it will never receive, so cycling power terminates the mode).

2.4.4 Motorinfo

`Motorinfo` is a standalone RPC client that allows one to request a display of the characteristics of a specified motor.

To use `motorinfo` one must provide an instrument-wide number (major), as specified in `nirc2_mechanism.config` (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)"), and which is correlated to a motor address (minor) in `nirc2_motor.config` (refer to Section 2.2 "Configuration file format").

As a minimum, the display consists of the major-motor number, associated motor address, and motor type. The information displayed is that which is loaded during motor daemon initialization from `nirc2_motor.config`.

2.4.5 Motorprop

`Motorprop` is a standalone RPC client that allows one to set a motor property variable to a specific string or retrieve the value of a motor property variable. The variables are essentially user variables that are retained in a hash table within the motor daemon (refer to Section 4.4 "User keywords") as a name-value pair, both of which must be strings.

Communications with motor controllers do not occur for these motor properties. The intent is that the hash table be used as a storage location for information that clients want to persist between invocations of the clients. However, the name-value pairs will be lost whenever the daemon is restarted.

To use `motorprop` for setting a motor property of one's choosing, two strings must be specified, the first being the motor property or keyword and the second being the associated value. Note that: all values are stored as strings, even those which are numeric; case is important as the keyword is stored exactly as entered, hence "`motor_name`" is different from "`Motor_name`," and the UNIX shell will often intercept punctuation characters so keywords or values containing non-alphanumeric characters or spaces must be enclosed in double quotes, which will be stripped by `motorprop`.

Examples are:

```
motorprop motor1 camera        - stores the keyword-value pair <motor1, camera>

motorprop motor1                    - returns "motor1 = camera"
motorprop "motor 2" grism

motorprop "motor 3" "inner filter wheel"
```

There is a significant amount of flexibility with the name-value pairs that can be stored in the motor daemon's hash table. There is support for this at the KTL keyword library level, in the form of "user" keywords, such that instrument scripts can communicate information with other scripts or between executions of a given script. The high level keywords can also be used within `xshow` or graphical user interfaces.

2.5 Building and releasing

The building of the motor daemon uses the Keck general make facility. This facility reduces the amount of `makefile` drudgery that a programmer would otherwise need to be concerned with. For a description of the make facility please refer to *KSD 31 /kroot Programming Manual*.

The basic recompilation command is simply "`gmake`." This will affect the sub tree in which the command is issued, but not the parent directories or release directories.

To recompile, link, and release the motor daemon libraries and include files, the command is "`gmake install`." This command will affect the entire motor daemon sub tree (/kroot/kss/ir_common/motor) as well as the release tree.

The release tree is /kroot/rel/default/… Releasing involves adding links to the release subdirectories of include and lib. The actual released files are written to subdirectories of /kroot/rel/default/Versions/motorDaemon/… However, the motor daemon executable is not built and released from within the `ir_common` sub tree. The motor daemon executable is built from /kroot/kss/nirc2/mech/daemons. This is because there are files that exist in other directories that must be linked into the daemon so as to tailor the daemon for the NIRC2 instrument.

Below the motorDaemon-release directory is a numeric subdirectory which corresponds to the current release version number as specified by the "`VERNUM`" statement in the Makefile within /kroot/kss/ir_common/motor. If a software specialist modifies any of the C modules used by the motor daemon then that person is expected to change the `VERNUM` statement. Doing this will preserve the current released files so reverting can be easily accomplished. If `VERNUM` is not changed, then the current release files will be overwritten when "`gmake install`" processes.

The software specialist is also expected to commit any changes with the appropriate CVS commands (refer to alternate documentation for CVS commands), including the modified Makefile.

Note that the files within /kroot/kss/ir_common and the util subdirectory must also be rebuilt upon occasion. This is done via a "`gmake install`" within `ir_common`.

3 I/O Daemon

The interface to the NIRC2 devices other than the motors (I/O modules) is via a body of software referred to as the I/O daemon. The I/O daemon is responsible for converting I/O demands and requests into syntactically correct I/O module-specific commands (DGH and Lakeshore language). Note that only a subset of the DGH and Lakeshore commands are encoded in the I/O daemon and, therefore, a finite set of possible calls exists. The implemented calls are enumerated in subsequent subsections.

The I/O daemon is a standalone task, which is intended to be executed when the NIRC2 control system host is booted.

Communication with the I/O daemon is via a set of RPCs, which are enumerated in subsequent subsections.

The normal mechanism for interfacing with the I/O daemon is via the KTL. This includes user command line use of "`show`," "`xshow`," and "`modify`," as well as, scripts and client programs. However, it is possible to create client programs that bypass the keyword layer and directly communicate with the I/O daemon via RPC calls. Such is the case of the standalone programs such as `telldevice` and `askdevice` (refer to Section 3.4 "Support programs").

For each I/O module/device type supported by the I/O daemon, a device-specific module must exist, hopefully, in an appropriately named subdirectory. As of November 2000, the I/O daemon supports DGH modules and Lakeshore devices. During startup configuration files are read and parsed. Some of the parsing is handled by functions in the device-specific modules in `dgh.c` and `lakeshore.c`.

Irrespective of the underlying device type on which an I/O signal exists, all keyword library interactions with the I/O daemon are via a set of RPC functions which are intended to be device- independent. In most cases, the RPC functions ultimately call functions in the device-specific modules. The device-specific modules' functions are not addressed herein. However, the RPC functions are discussed in the following subsections.

3.1 RPC functions

As previously mentioned, the interface to the I/O daemon is via a set of RPC functions. The intent is that the keyword software and/or client programs need not know any of the underlying device-specific commands/language but, rather that certain I/O functions are supported. The keyword library translates the analog and digital keywords into the appropriate RPC calls to the I/O daemon, thus, the following information is provided for the requirements imposed on any new client programs.

Rather than creating a specific RPC function for every possible I/O function, or subset thereof, the I/O functions were grouped into analog input, analog output, digital input, digital output, and six other special purpose RPC functions.

In the following subsections there are frequent references to "client." One client is the keyword library itself, which uses most if not all of the RPC functions. However, the keyword library is not, and need not be, the only client. For instance the I/O daemon support programs (refer to Section 3.4 "Support programs") are also clients.

3.1.1 Data structures

The nature of an RPC interface is such that each RPC function takes a pointer to an argument, which may be a scalar or a structure, and returns a pointer to a scalar or structure. It is the calling program's responsibility to free the memory for the returned item.

The data structures for the I/O daemon's RPC functions are `ioInfo()`, `ioMsg()`, `ioProp()`, ioSts(), ioReply(), and ioStrReply(), which are defined in io.h and derived from `io.x`.

Note that the data structures returned from RPC calls must be explicitly deallocated with `xdr_free()`. If this were not done then a memory leak would exist.

3.1.1.1 ioInfo

The `ioInfo` structure is used in two of the I/O daemon's RPC calls (`iowrite_1` and `ioread_1`). This structure allows a client to specify the details about a signal for which a value is to be fetched or set.

The `ioInfo` structure consists of:

1. a channel (signal number) field;
2. a board (device number) field;
3. a raw flag to specify whether or not the values should be manipulated as per any scale and offset or lookup table which may have been specified in the `nirc2_io.config` file (refer to Section 3.2 "Configuration file format");
4. an `ioType` field which identifies the type of signal for which the value is pertinent where the type is one of the enumerations in IO_TYPE within `interface.h`;
5. a flag field which indicates whether the value is an unsigned long or a double real;
6. an unsigned long field which holds the value if the flag field is set; and
7. a double field which holds the value if the flag field is not set.

Note that the possible types are device-specific. For instance, the Lakeshore temperature controller has set points and heater values, as well as thermal inputs, and some of the DGH modules have analog as well as digital signals.

3.1.1.2 IoMsg

The `ioMsg` structure is used in two of the I/O daemon RPC calls (`telldevice_1` and `askdevice_1`). This structure allows a client to send/receive arbitrary strings to/from an I/O device. The string is not parsed or interpreted; hence, it is the client's responsibility to ensure a command string is valid with respect to the remote device's command syntax.

The `ioMsg` structure consists of an integer field "`board`" which is the device number of the remote device with which a transaction will occur and a string field "`msg`" that hold the command or response. Client programs must allocate the space for the string fields.

3.1.1.3 IoProp

The `ioProp` structure is used in the I/O daemon's `setioprop_1` and `getioprop_1` RPC calls. This structure allows clients to store arbitrary `<name, value>` strings in a hash table within the I/O daemon. The intent is to store values which a client would later retrieve for internal use. This concept is discussed in more detail within a subsection about "user variables" in the Keyword Library documentation (refer to Subsection 4.4 "User keywords").

The `ioProp` structure consists of two character pointer fields, namely, "`name`" and "value." The client must allocate the space for the strings.

3.1.1.4 IoSts

The `ioSts` structure is returned to a client in response to `finddevice_1, setioprop_1, telldevice_1,` or `iowrite_1` RPC call. The intent is to return status information to a client which issued a command to some remote device.

The `ioSts` structure consists of an integer status field, which is set to 1 on success, and a string, which holds any error message, associated with a status value other than 1.

3.1.1.5 IoStrReply

The `ioStrReply` structure is returned to a client in response to a `getioprop_1`, `askdevice_1`, or `getinfo_1` RPC call. All of these calls return string data to the client.

The `ioStrReply` structure consists of a status field, which is set to 1 when an error did not occur, an error message string and a response message string.

3.1.1.6 IoReply

The `ioReply` structure is returned to a client in response to an `ioread_1` RPC call. The structure only provides for scalar values.

The `ioReply` structure consists of:

1. a status field which is set to 1 on success;
2. an error message string which is typically set when the status is not 1;
3. a flag field which indicates whether or not the value is returned as a double or unsigned long value;
4. an unsigned long value field which is set to the return value if the integer flag field is set; and
5. a double value field which is set to the return value if the integer flag field is not set.

Note that the flag field is controlled within the device-specific protocol routine, which, in this case, is handled within `lakeshore.c` or `dgh.c`.

3.1.2 Adding new I/O types

At some point in time it may be necessary to support additional types of device signals. To do so one would need to extend the I/O type enumerations (`io_type` in interface.h) and then add a case statement to the relevant functions in the device-specific modules (lakeshore.c or dgh.c). If a new device command must be added to the keyword library then either a function must be modified in `io.c` or a new function must be added to `io.c`.

3.2 Configuration file format (nirc2_io.config)

When the I/O daemon initializes, it reads and parses the records contained in a configuration file. The configuration file is specified in the default script provided as a daemon command line argument. Throughout this manual the configuration file is referred to as `nirc2_io.config`, however, it is possible to change this in the default script, which one may wish to do for testing and/or troubleshooting.

The I/O configuration file has three functions:

1. to identify the communications links
2. to identify the devices connected to a given link, and
3. to specify the characteristics of each of those devices.

More than one communications link may be specified but all devices and their characteristics, for a given link, must be specified before another link is specified. That is, all device information following a communications link is assumed to be relevant to that communications link, up to the point that another communications link is specified.

3.2.1 Communications link specifications

The purpose of a communications link specification is to identify the physical port on which one or more remote I/O devices are connected.

The devices may be connected to a host (UNIX machine) serial port, in which case the syntax would be:

```
serial <port name>
```

Where the "`port name`" is the string as specified in the host's device table (e.g., /dev/term/b).

Alternatively, the devices may be connected to a terminal server port, in which case the syntax would be:

```
ethernet <host id> <port number>
```

Where "`host id`" would be the terminal server name/IP address and "`port number`" is the terminal server port to which the remote device is connected (e.g., ethernet nirc2ts1 3003).

3.2.2 I/O device specification

For each I/O device connected to a communications link there must be a device specification followed by any optional device characteristic specifications.

The syntax for the device specification is:

```
device=<device type> <major device number> <minor device number>
```

```
{icd=<microseconds>}
```

Where:

`Device type` for NIRC2 is any of the DGH modules (D1712, D1132, or D4172), or the Lakeshore devices (L218S or L340).

The "`major-device number`" is the instrument-wide number (refer to Section 2.2.2 "Motor specifications").

The "`minor-device number`" is the device address or number to which a specific device, on a given communications link, will respond.

`Icd` is an inter-character delay used when writing to the communications link.

The motor daemon determines which device-specific configuration routines to call from the device types.

If "`icd`" is not specified then characters are output in bursts, and fragmentation by the UNIX driver and/or terminal server may have an affect and, in some cases, the remote device may not be able to keep up. In other cases the remote device may not accept delays between characters greater than 100 milliseconds. In general, the inter-character delay is very device-specific and typically requires tests to determine whether or not it is necessary. The devices on NIRC2 are set so that data is in burst mode to the Lakeshore temperature monitors and there is a one-millisecond inter-character delay for the Lakeshore temperature controller and all of the DGH modules.

3.2.3 I/O device characteristics

A device may possess a set of characteristics, which can be specified in the configuration file. The set of allowed characteristics depends upon the I/O module type (for NIRC2 that is the two different Lakeshore devices and the three different DGH modules).

Each characteristic must exist on a separate line in the configuration file.

3.2.3.1 Digital signal characteristics

The syntax for the currently allowed digital I/O characteristics is:

```
[DIN | DOUT | DIO] = <hex bit pattern>
```

The `DIO` characteristic allows one to specify the I/O directions (input or output) of the signals, on modules that permit such configuration. For each signal that is an output, the corresponding bit in the bit mask must be a 1. Conversely, input signals must be designated with a 0.

The `DIN` and `DOUT` characteristics allow one to designate the active states of the digital I/O signals. For digital inputs, the value obtained for a device is XOR'd with the mask before being returned from the

daemon. For digital outputs, the output value is exclusive ORed with the mask before being sent to the module/device. This allows one to hide negative logic from the keyword library and, hence, the users/clients.

3.2.3.2 Analog signal characteristics

The syntax for the currently allowed analog I/O characteristics is:

```
[DAC | ADC] <chan num> {scale=<real num>} {offset=<real num>}
   {breaktable
<value pair list>
     end}
```

Where: `DAC` or `ADC`, and "`chan num`" must be present; if scale is omitted then it defaults to 1.0; if offset is omitted then it defaults to 0.0; the breaktable value pairs must each be on a separate line and, the ordering of the pairs is keyword side followed by device side (i.e., the second value is that which will be output to a device – DAC value – or the key for lookups on device reads – ADC value); the breaktable "`end`" statement must be on a separate line. Note that linear interpolation is performed on the breaktable values. As of July 2001, no break tables are used on the NIRC2 devices.

3.3 Logging and debugging

I/O daemon logging has been implemented with the UNIX facility `syslog`. The calls within the I/O daemon are to `errlog()`, which actually performs the `syslog` calls, thereby providing some insulation from changes in the logging mechanism.

The syslog logging level can be controlled in two ways. First, logging can be controlled by setting the environment variable `LOG_UPTO` in the context within which the motor daemon is started. The values for this are provided by the lev_array within $KROOT/kss/ir_common/util/arg_functions.c (emerg, alert, crit, err, warning, notice, info, debug) where the higher priority logging levels are given first.

The second means of controlling the I/O daemon's logging level is via a command line argument when the daemon is started. One must follow the parameter "`-log_upto`" by one of the previously mentioned levels.

Both of the aforementioned mechanisms for controlling the logging level are handled by the call to setup_openlog() within $KROOT/kss/ir_common/io/daemon/ioCalls.c.

Assuming the logging level is appropriately set (typically debug), then the amount of information logged by the I/O daemon can be controlled dynamically via the `IODTRACE` keyword and, at the device specific level (dgh.c and lakeshore.c) via the relavent …tell keywords, which must be used in this fashion:

```
modify –s nirc2 ltc5tell=”TRACE=7”
```

The previous command (the case of trace is significant) would set the trace/logging level within lakeshore.c.

Setting the trace level to 1 or greater will cause the lakeshore functions to log a message on exit, which will include the function's status, and, for those that return data, the data.

If the trace level is set to a value greater than 2, then the lakeshore I/O functions (`sendCmd()` and `getAnswer()`) will print all strings transmitted and received to standard output. If the trace level is set to a value greater than 3, then those same functions will also generate the same information in the log file.

Numerous messages may be logged. The messages are intended to be self-explanatory, so no attempt is made, herein, to describe the troubles that would cause a given set of logged messages.

3.4 Support programs

Support programs exist for the purposes of troubleshooting, integration, and I/O module setup. These programs are intended to be used by the instrument software specialist and/or the instrument specialist, but not the user community.

The support programs bypass the keyword library and interface directly to the I/O daemon via the RPC interface.

The support programs are software modules written in the C programming language.

3.4.1 Askdevice

`Askdevice` is a standalone RPC client that allows one to issue a command string, to a specific device, via the I/O daemon, in response to which the device will return some value. As only a subset of the devices' commands is programmed into the I/O daemon (refer to the DGH and Lakeshore User's Manuals for a description of valid commands), this function provides a client with the ability to use various other commands.

To use `askdevice` one must provide an instrument-wide major-device number (refer to Section 2.2.2 "Motor specifications") and a request string. The major device number is used, by the daemon, to locate the communications link and device address (minor device number) of the associated physical module/device. The device address is prepended to the request string before that string is transmitted to the device.

The request string must be formatted in the device-specific language and syntax. Thus, one must be familiar with the DGH and Lakeshore commands as specified in their various Users' Manuals. The DGH and Lakeshore devices typically ignore unknown strings, which will then result in a "`serial IO failed`" error.

If a command string is longer than a single word and/or contains non-alphanumeric characters, then it must be enclosed in double quotes.

A command string can contain embedded backslash sequences for either octal or the standard carriage return, line feed, tab and so forth. The program will translate those sequences into their single byte equivalents prior to sending the request to the I/O daemon.

An example to request the value of analog input channel 0 on DGH device 4 (which we assume, for this example, is an analog input module such as D1132):

```
askdevice 4 RD
```

An example to request the value of the ADC feedback channel on a DGH analog output module (D4172, assumed to be device 1 for this example):

```
askdevice 1 RAD
```

An example to request the device setup of device 3:

```
askdevice 3 RS
```

3.4.2 Telldevice

`Telldevice` is a standalone RPC client that allows one to issue a command string to a specific device, via the device daemon. As only a subset of the devices' commands is programmed into the I/O daemon (refer to the DGH and Lakeshore User's Manuals for a description of valid commands), this function provides a client with the ability to use various other commands.

To use this `telldevice` one must specify an instrument-wide/major-device number (refer to Section 2.2.2 "Motor specifications") and a request string, which must be formatted in the device-specific syntax (DGH or Lakeshore for NIRC2). The major device number is used, by the daemon, to lookup the specific device address (minor device number) and communications link of the associated physical device/module. The device address is prepended to the request string before that string is transmitted to the device.

The request string is not parsed and, therefore, is assumed to be syntactically correct for the device. Thus, one must be familiar with the DGH and Lakeshore commands as specified in their various Users' Manuals. The DGH and Lakeshore devices typically ignore unknown strings, which will then result in a "`serial IO failed`" error.

If a request string is longer than a single word and/or contains non-alphanumeric characters, it must be enclosed in double quotes.

A request string can contain embedded backslash sequences for either octal or the standard carriage return, line feed, tab and so forth. The program will translate those sequences into their single-byte equivalents prior to sending the request to the I/O daemon.

An example to set the analog output on device 1 (assumed, for this example, to be an analog output device D4172):

```
telldevice 1 AO+00010.00
```

An example to do a write enable (allows updates to non-volatile memory) on device 3:

```
telldevice 3 WE
```

An example to update the setup on device 3 (assumed to be a DGH analog output D4172):

```
telldevice 3 SU330202C4
```

Refer to the DGH manual for the description of the setup bits.

3.4.3 Showdevinfo

`Showdevinfo` is a standalone RPC client that allows one to request a display of the characteristics of a specified device. The client effectively causes an RPC call within the I/O daemon.

To use this program one must specify an instrument-wide major device number, which is used, by the daemon, to look up the specific device address (minor device number) and communications link. If one specifies a device number of 0 or less, then the information for all configured devices is displayed.

The display consists of: the major-device and minor-device numbers (refer to Section 2.2.2 "Motor specifications"); the I/O type (`AIN, AOUT, AIO, DIN, DOUT, DIO,` or `UNKNOWN`), the manufacturer device type (D1132, D4172, D1712,...); the number of digital input and output signals; and the number of analog input and output signals.

If one specifies a number for a device, which is not configured, then '`UNDEFINED`" is displayed. Similarly, '`MAX='n'`" is displayed for a specified device number which is greater than the highest numbered device configured.

3.5 Building and releasing

The building of the I/O daemon uses the Keck general make facility. This facility reduces the amount of `makefile` drudgery that a programmer would otherwise need to be concerned with. For a description of the make facility please refer to *KSD 31 "/kroot Programming Manual*."

The basic recompilation command is simply "`gmake`." This will affect the sub tree in which the command is issued, but not the parent directories or release directories.

To recompile, link, and release the motor daemon the command is "`gmake install`." This command will affect the entire motor daemon sub tree (/kroot/kss/ir_common/io) as well as the release tree.

The release tree is /kroot/rel/default/… Releasing involves adding links to the release subdirectories of include and lib. The actual released files are written to subdirectories of /kroot/rel/default/Versions/ioDaemon/… However, the I/O daemon executable is not built and released from within the ir_common sub tree. The I/O daemon executable is built from

/kroot/kss/nirc2/mech/daemons. This is because there are files that exist in other directories that must be linked into the daemon so as to tailor the daemon for the NIRC2 instrument.

Below the ioDaemon-release directory is a numeric subdirectory that corresponds to the current release version number as specified by the "`VERNUM`" statement in the Makefile within /kroot/kss/ir_common/io. If a software specialist modifies any of the C modules used by the ioDaemon then that person is expected to change the `VERNUM` statement. Doing this will preserve the current released files so reverting can be easily accomplished. If `VERNUM` is not changed, then the current release files will be overwritten when "`gmake install`" processes.

The software specialist is also expected to commit any changes with the appropriate CVS commands (refer to alternate documentation for CVS commands), including the modified Makefile.

Note that the files within /kroot/kss/ir_common and the subdirectory `util` must also be rebuilt upon occasion. This is done via a "`gmake install`" within `ir_common`.

4 Keyword Library

Control of the NIRC2 mechanisms and I/O devices is provided by the standard KTL keywords and the associated `show`, `xshow`, and `modify` programs. More sophisticated clients can be constructed in which case they would need to interface to KTL via the functions contained in software modules such as `ktcl` and `kidl`. The UCLA graphical user interface uses `kidl` to interface to the detector system and various other NIRC2 GUIs use `ktcl` (the status window interfaces to the detector keyword library as well as the mechanisms keyword library).

A complete description of KTL can be found in KSD 28, however, a brief overview follows.

KTL consists of a set of routines, which interface to various control systems by locating shareable libraries that are tailored for those systems. The functions in the libraries must implement a generic set of routines, which serve as the interface between KTL and the independent systems. The generic routines are analogous to the device drivers on most modern operating systems, namely, `keyword_open()`, `keyword_ioctl()`, `keyword_read()`, `keyword_write()`, and `keyword_close()`. Those systems, which need to provide asynchronous updates, must also implement `keyword_event()` and `keyword_respond()`.

The link between a shareable library and a specific control system is provided by the "`service`" name, which is typically an acronym for the control system. This constrains the spellings of the shareable libraries to be of the form `lib<service>_<text>.so.0.0`. For instance, the NIRC2 mechanism keyword library is `libnirc2_keyword.so.0.0` and the NIRC2 detector keyword library is `libalad_keyword.so.0.0` (where the acronym is for Aladdin).

When a client calls `keyword_open()` the actual processing is specific to the requirements of the control system for which the library was created. The NIRC2 detector system software consists of an RPC server, which possesses the knowledge of all the detector keywords, hence the keyword library functions simply make RPC calls to that server (refer to the UCLA detector documents). The NIRC2 mechanism software consists of two RPC daemons (as described in previous sections), but those

daemons are essentially communications agents and the keyword knowledge is contained within the functions of the keyword library.

The phrase "NIRC2 keyword library" will refer to the NIRC2 mechanism keyword library, unless explicitly stated otherwise, in the remainder of this section.

Many keyword libraries have the details of their keywords implemented as static structures in a list. The NIRC2 keyword library builds its keyword table from configuration files (refer to Section 4.5.1 "Nirc2_config_file (keyword characteristics)"), which are read when a client invokes `keyword_open()`. The configuration files can be dynamically modified, although it is expected that an instrument specialist will rarely do modifications on those files. When one of the keyword programs is used, the KTL layer causes the keyword library (`libnirc2_keyword.so.0`) to be instantiated. In the case of `show` and `modify`, the keyword library terminates when the requested action is complete. In the case of `xshow`, the library persists until `xshow` is terminated.

When the one-shot utilities (`show` and `modify`) are invoked the NIRC2 keyword library configures itself, processes the command, and terminates. Thus, there is no persistence within the keyword library, between keyword commands. Any persistence is a function of the daemons and the functions in the keyword library make extensive use of the hash tables maintained by the daemon. Thus, the keyword library is essentially a conduit for translating mechanism specifics into device specifics.

The keyword library can be conceptualized as two layers each layer of which could have its own set of keywords.

A low-level layer of keywords provides an interface to the mechanisms that is more or less device specific. For instance, motor-control keywords would allow one to move a motor to a specified position but would not provide feedback during that move, a sort of fire-and-forget control mode. This layer of control would not understand that a given mechanism was a wheel or slider stage but simply that a motor is associated with the keyword for which a set of operations exists. For this level of control the functions in the files (`analogKeyword.c`, `digitalKeyword.c`, `ioKeyword.c`, and `motorKeyword.c`) within /kroot/kss/ir_common/keyword, utilize the functions contained in `motor.c` and `io.c` to interface with the motor and I/O daemon tasks (refer to Sections 2 and 3).

A higher-level layer of keywords provides an interface to the mechanisms that is more of a logical device level. The associated keywords use the functions in the files (`mechanisms.c`, `wheels.c`, and `sliders.c`) within /kroot/kss/nirc2/mech/keyword to utilize the functions within `motor.c` and `io.c` to interface with the motor and I/O daemon tasks. The higher-level functions understand that a given mechanism is either a wheel or slider stage and implement algorithms pertinent to the type of the mechanism.

The distinction between the two levels of keywords is provided within the keyword configuration file (`nirc2_config_file`).

The keywords can be categorized as mechanism keywords, motor keywords, I/O keywords, and user keyword. Each of these categories is described in subsequent subsections.

4.1 Mechanism keywords

Mechanism keywords refer to the keywords that are associated with the NIRC2 motor-controlled mechanisms that have a higher-level abstraction than simply a motor. There is a set of keywords associated with each of the NIRC2 cryogenic mechanisms. The exact set of keywords that exists is provided by a configuration file (refer to Section 4.5.1 "Nirc2_config_file (keyword characteristics)").

4.1.1 Keyword naming conventions

In general, the mechanism keywords consist of a prefix and a suffix, such that the prefix is tied to a specific mechanism via a configuration file, and the suffix is essentially a logical command or logical operation to be performed on the mechanism.

The prefixes are used by the keyword library functions to find the mechanisms' characteristics that are read from the relevant configuration files when the keyword library is invoked, and to determine which mechanisms' functions to invoke (`wheels.c` or `sliders.c`).

Keyword suffixes are used by the keyword library functions to determine which specific functions within `wheels.c` and `sliders.c` to invoke. The invoked functions then drive the relevant motors as per the functionality implied by the suffix (logical operation). Associations between the keyword suffixes and logical operations are provided by hard-coded lists (`WheelTable` and `SliderTable`) within `wheels.c` and `sliders.c`. The contents of these tables are entered into hash tables when the keyword library is invoked such that subsequent read and/or write requests, for the suffixes, will efficiently find the necessary C functions to call.

Restrictions in the spelling of mechanism keywords exist as there must be some relation between a keyword and the desired function commanded of a specific mechanism. The prefixes are restricted in spelling to those specified in `nirc2_mechanism.config` (refer to Section 4.5.1 "Nirc2_config_file (keyword characteristics)") and the suffixes are restricted to the spellings within the aforementioned `WheelTable` and `SliderTable` lists. Note that the spelling of some keywords is a little cryptic. This was done for those keywords that one might want included in a fits header, as fits header keywords are restricted to a maximum of eight characters.

As there are eleven motor controller mechanisms, on the NIRC2 instrument, there are eleven mechanism keyword prefixes: `CAM` for the camera slide; `GRS` for the grism slider; `SHR` for the shutter whose type is designated as a slider; `FWI` for the inner filter wheel; `FWO` for the outer filter wheel; `PMS` for the pupil mask selector wheel; `PMR` for the pupil mask rotator (keywords exist for this only for integration and testing as it is implemented differently for the other mechanisms as specified in Section 7 "Pupil Mask Rotator"); `SLS` for the slit slider; `SLM` for the slit mask slider; `PSI` for the inner preslit slider; and `PSO` for the outer preslit slider.

4.1.2 Mechanism keyword types

Two major types of mechanism keywords exist: wheel mechanism keywords which are associated with mechanisms that are rotated to discrete positions, and slider mechanism keywords which are associated with mechanisms that are linearly translated to discrete positions. Note that the pupil mask rotator keywords are not included with the mechanism keywords (the pupil mask rotator is expounded upon in Section 7 "Pupil Mask Rotator").

The depiction of whether a mechanism is a wheel or a slider is specified in both of the keyword library configuration files (refer to Section 4.5 "Configuration Files") and is referred to as the keyword type. The keyword type is retained within the data structures constructed within `wheels.c` and `sliders.c` when the configuration files are read upon keyword library startup.

Another small category of keywords exists, which is composed of a few miscellaneous keywords that are not associated with specific mechanisms. These keywords are essentially hard-coded within the C modules and are not a composite of prefixes and suffixes.

4.1.3 Mechanism operations relating to keyword suffixes

Numerous operations can be performed on the instrument mechanisms. Most of those operations are identical or at least analogous between the wheel and slider mechanisms. One exception to this is the suffix relating to the mechanisms' positions, in engineering units, as the wheels' positions are expressed as angular measures in degrees and the sliders' positions are expressed as displacements in millimeters. Consequently, the keyword suffixes, for these measures, differ between wheel and slider mechanisms.

Some of the mechanism operations imply read-only mechanism keywords and vis-à-vis others imply write-only. For instance, `FWOSTAT` would be a read-only keyword, which provides the current motion state of the outer filter wheel, whereas `FWOSTOP` would be a write-only keyword, which would cause the outer filter wheel to stop its current motion.

The keyword suffixes provide a logical set of operations that a client is permitted to perform on the instrument mechanisms. To cause an operation to happen, the functions within `mechanisms.c`, `sliders.c`, and `wheels.c` are invoked. These functions, in turn, invoke functions within `motor.c` to interface with the motor daemon, which handles the command transactions with the motors.

Each of the keyword suffixes is discussed in detail within the following subsections. The C functions calling sequence, for reading and writing of each of the keywords that are constructed from the suffixes, are included with the suffix descriptions.

4.1.3.1 ACCEL

The `ACCEL` suffix refers to a mechanism's motor acceleration parameter. As of November 2000, this is a write-only operation.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

Writing to an acceleration keyword will invoke either `sliderDynamics()` within `sliders.c` or `wheelDynamics()` within `wheels.c`, as per the keyword type, which is implied by the keyword prefix. The complete calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderDynamics or wheelDynamics (sliders.c or wheels.c)
motorSetAcceleration -> motorCmd   (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.1.3.2 ACTIVE

The `ACTIVE` suffix refers to a mechanism's current/impending motion state.

When a function is called which will cause a mechanism to move, whether from a homing, absolute position, or delta position command, the motion control function will set and store an active flag for that mechanism. This is done even before the motion commands are issued to the relevant motor. Note that the C code does not clear the active flag, as clearing the flag is the responsibility of the client programs.

This functionality was added during motor repeatability tests so that scripts could initiate parallel motor moves and then determine when all such moves commenced before proceeding to the next step in the script. Of course, those scripts would have to reset all the active flags.

Note that the active flags are analogous to "user keywords," as described in Section 4.4 "User keywords," because their values are stored in a hash table within the motor daemon.

The calling sequences for reading an `ACTIVE` keyword follows.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

The calling sequences for writing an `ACTIVE` keyword follows.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
```

```
setMotorProp (motor.c)
setmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
setmotorprop_1 (clientFuncs.c)
propSetString (properties.c)
```

4.1.3.3 AMPS

The AMPS suffix refers to a mechanism's maximum motor current parameter. As of November 2000, this is a write-only operation. This keyword has aliases that are: CURRENT, and CRNT. As of the aforementioned date only the AMPS suffix is used in the configuration file.

Note that the non-operational keywords of this type may be removed from the default configuration file nirc2_config_file at some point.

Writing to an amperage keyword will invoke either sliderDynamics() within sliders.c or wheelDynamics within wheels.c, as per the keyword type, which is implied by the keyword, prefix. The calling sequences for writing an AMPS keyword follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderDynamics or wheelDynamics (sliders.c or wheels.c)
motorSetCurrent  -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.1.3.4 BLASH

The BLASH suffix refers to a mechanism's backlash offset. As of November 2000, this is a write-only operation. This keyword has the alias BACKL, but as of the aforementioned date only the BLASH suffix is used in the configuration file.

The backlash offset is applied within the motor controllers' subroutines for motor moves (refer to Section 9.1 "Animatics motor programs"). Although this parameter is dynamically modifiable, the intent is that once instrumentation integration is complete this parameter will seldom, if ever, be changed.

Note that the non-operational keywords of this type may be removed from the default configuration file nirc2_config_file at some point.

Writing to a backlash keyword will invoke either sliderDynamics() within sliders.c or wheelDynamics within wheels.c, as per the keyword type, which is implied by the keyword, prefix. The calling sequences for writing a backlash keyword follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderDynamics or wheelDynamics (sliders.c or wheels.c)
motorSetBackLash -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.1.3.5 BRAKES

The BRAKES suffix refers to a mechanism's brakes. Under normal operations the brakes are automatically released and set, at the appropriate times, by the motor controller subroutines (refer to Section 9.1 "Animatics motor programs"). However, this functionality is provided for troubleshooting mechanism problems. Specifically, the BRAKES keywords, in conjunction with the ENABLE keywords, would allow one to "free-wheel" a mechanism.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

Writing to a backlash keyword will invoke either `sliderDynamics()` within `sliders.c` or `wheelDynamics` within `wheels.c`, as per the keyword type, which is implied by the keyword, prefix. The calling sequences for writing a BRAKES keyword follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderDynamics or wheelDynamics (sliders.c or wheels.c)
motorBrakes -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.1.3.6 DELTA

The DELTA suffix refers to moving a mechanism a relative distance from its current position. This suffix has an alias of DEL, which is not used, in the configuration file of as November 2000.

The composite keywords can be written. When written to the keywords they will typically initiate motor motion and will cause the keywords with suffixes TARG and DEST to be updated (refer to Sections 4.1.3.8 "DEST" and 4.1.3.29 "TARG).

The displacement keywords are write-only keywords which will invoke either `moveSliderCmd()` within `sliders.c` or `moveWheelCmd()` within `wheels.c`, as per the keyword type which is implied by the keyword prefix. The calling sequences for writing displacement keywords follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
moveSliderCmd or moveWheelCmd -> moveSlider or moveWheel
(sliders.c or wheels.c)
motorMove -> motorCmd  (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.1.3.7 DESCR

The `DESCR` suffix provides clients the ability to obtain a descriptive string for a given mechanism. The descriptions are those specified in `nirc2_mechanism.config` (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)"). The intent is to provide information for user interfaces.

The `DESCR` keywords are read-only keywords which cause either the `sliderInfoFn()` function or the `wheelInfoFn()` function, within `sliders.c` and `wheels.c`, to be invoked as per the mechanism type. The complete calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderInfoFn or wheelInfoFn (sliders.c or wheels.c)
```

4.1.3.8 DEST

The `DEST` suffix provides clients read-only keywords, which specify the raw encoder positions to which mechanisms were last commanded to acquire.

The destination keywords are analogous to "user keywords" (refer to Section 4.4 "User keywords) in that their values are retained in a hash table within the motor daemon.

The destination keywords are updated whenever mechanism motion keywords are written.

Reading a destination keyword causes either the `sliderRequest()` function or the `wheelRequest()` function, within `sliders.c` and `wheels.c`, to be invoked as per the mechanism type. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.1.3.9 DIST or ANGL

The DIST and ANGL suffixes refer to mechanisms' positions in engineering units. For wheel mechanisms the angular measure is in degrees and for slider mechanisms the distance measure is in millimeters. The values are relative to mechanisms' home locations.

The composite keywords can be read and written. When written to the keywords they will typically initiate motor motion and will cause the keywords with suffixes TARG and DEST to be updated (refer to Sections 4.1.3.8 "DEST" and 4.1.3.29 "TARG). However, once motor motion commences, reading the DIST and ANGL keywords will provide values that reflect the mechanisms' current positions and not the values to which they were set. Thus, as the motors move, the keywords will be continually changing until motor motion stops, which, if the positions are successfully attained, will then have values agreeing with the TARG keywords and be consistent with the values to which the DIST and ANGL keywords were originally written.

Writing the position keywords will cause either the moveSliderCmd() function or the moveWheelCmd() function to be invoked. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
moveSliderCmd or moveWheelCmd -> moveSlider or moveWheel
(sliders.c or wheels.c)
motorMove -> motorCmd  (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderPositionSts or wheelPositionSts -> updatePosnFeedback
(sliders.c or wheels.c)
motorTellPosition -> motorSts (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.1.3.10 ENABLE

The ENABLE suffix provides composite mechanism keywords, which allow clients to enable and disable the mechanisms' motor servos (vis-à-vis motor power or holding torque).

Under normal operations the motor servos are automatically enabled and disabled, at the appropriate times, by the motor controller subroutines (refer to Section 9.1 "Animatics motor programs"). However, this functionality is provided for troubleshooting mechanism problems. Specifically, the ENABLE keywords, in conjunction with the BRAKE keywords, would allow one to "free-wheel" a mechanism.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

The ENABLE keywords are write-only and cause either the `sliderCommand()` or the `wheelCommand()` functions, within `sliders.c` and `wheels.c`, to be invoked as per the mechanism type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
motorPower -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.1.3.11 HOME

The HOME suffix provides for mechanism keywords, which will cause mechanisms to find their "home" positions and to provide feedback as to whether or not the mechanisms have been homed since their last software resets or power cycles.

The Animatics Smartmotors do not provide homing commands or statuses so, on NIRC2, the functionality is provided by homing subroutines, which are downloaded into the motor controllers' non-volatile memories (refer to Section 9 "Animatics Motor Controllers"). At the end of the homing subroutines a motor controller variable is set to indicate that homing is complete. It is the value of the internal motor controller variable that is returned when a HOME keyword is read. Note that all motor controller variables default to 0 upon a software reset or power cycle.

Whereas writing a HOME keyword will invoke either the `homeSliderCmd()` function or the `homeWheelCmd()` function within the same C modules. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
homeSliderCmd or homeWheelCmd -> homeSlider or homeWheel
(sliders.c or wheels.c)
motorHome -> motorCmd  (motor.c)
```

```
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

When a `HOME` keyword is read either the `sliderHomeSts()` function or the `wheelHomeSts()` function, within `sliders.c` and `wheels.c`, is invoked as per the mechanism type. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderHomeSts or wheelHomeSts (sliders.c or wheels.c)
motorTellHomingPosition -> motorSts (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.1.3.12 IDLE

The `IDLE` suffix provides for mechanism keywords, which will provide clients with the current idle status of the associate motor where idleness means that the motor is not currently moving.

The Animatics Smartmotors do not provide for status commands that would explicitly indicate whether or not a motor is idle. On NIRC2 this was implemented by always setting a specific motor controller variable prior to executing a motor controller subroutine – the subroutines are downloaded into the motor controllers' non-volatile memories – and those subroutines always clear that variable just before exiting. In this way the motor controllers' variables can be read to determine whether or not they are 0 and, hence, whether or not the controller is idle.

The `IDLE` keywords are read only and cause either the `sliderIdleSts()` function or the `wheelIdleSts()` function, within `sliders.c` and `wheels.c`, to be invoked. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderIdleSts or wheelIdleSts (sliders.c or wheels.c)
motorIsIdle -> motorSts (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.1.3.13 INFO

The `INFO` suffix allows mechanism keywords to provide clients with mechanism-specific information, which was previously loaded from configuration files (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)"). The intent is to provide users with names and position information for when they have memory lapses, of course the information could also be parsed by user interfaces so that they can self-configure themselves.

Information provided consists of: the mechanism's associated motor number, encoder resolution, and number of discrete positions; for each discrete position the position name, number, position value in engineering units, positioning accuracy, and absolute encoder position are provided.

The `INFO` keywords are all read-only and invoke either the `sliderShowInfo()` function or the `wheelShowInfo()` function, within `sliders.c` and `wheels.c`, as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderShowInfo or wheelShowInfo (sliders.c or wheels.c)
```

4.1.3.14 INIT

The `INIT` suffix provides for mechanism keywords to either initialize mechanisms and/or provide feedback on whether or not mechanisms have been initialized since they last experienced a software reset or power cycle.

The Animatics Smartmotors default to a set of motor-control parameter values, which do not permit the motors to be moved. To alleviate this, an initialization subroutine was downloaded into each of the motor controller's non-volatile memory. The subroutines set the motor control parameters to safe values, which will allow the motors to be moved albeit not necessarily at their optimums. The `INIT` keywords cause the initialization subroutines to be executed.

At the end of the initialization subroutines, motor controller variables are set to indicate that initialization has been performed. The values of the internal motor control variables are returned when `INIT` keywords are read.

Writing an `INIT` keyword will invoke either the `sliderCommand()` function or the `wheelCommand()` function within `sliders.c` or `wheels.c`, as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
motorInitialize -> motorCmd  (motor.c)
```

```
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

When an `INIT` keyword is read either the `sliderRequest()` function or the `wheelRequest()` function, within `sliders.c` and `wheels.c`, is invoked as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
motorTellInitSts -> motorSts (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.1.3.15 KILL

The `KILL` suffix provides for keywords to abruptly stop mechanisms' motors.

In practice these keywords do not behave as expected. All motor motions are performed by invoking subroutines which are stored in the motor controllers' non-volatile memories, in most cases, the subroutines perform two moves so as to compensate for backlash, and there is no mechanism for terminating a subroutine that is executing, short of a software reset. As a result, a `KILL` will usually occur before the backlash move, thus, only the "slew" will be killed and the backlash move will still occur.

If a true kill is needed, the user should cause a software reset to occur (refer to Section 4.1.3.25 "RESET").

The `KILL` keywords are write-only and invoke either the `sliderCommand()` function or the `wheelCommand()` function, within `sliders.c` and `wheels.c`, as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderCommand or wheelCommand(sliders.c or wheels.c)
killMechanism (mechanisms.c)
motorKill -> motorCmd (motor.c)
```

```
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.1.3.16 LMTORIDE

The `LMTORIDE` suffix provides keywords for overriding a mechanism's software limits. This would typically not be done during normal operations, but is often useful when troubleshooting or calibrating after a mechanism has been physically altered.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

Writing a limit override keyword will invoke either the `sliderCommand()` function or the `wheelCommand()` function within `sliders.c` or `wheels.c`, as per the mechanism's type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
setMotorProp (motor.c)
setmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
setmotorprop_1 (clientFuncs.c)
propSetString (properties.c)
```

Reading a `LMTORIDE` keyword will invoke either the `sliderRequest()` function or the `wheelRequest()` function, within `sliders.c` and `wheels.c`, as per the mechanism type. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.1.3.17 MAXPE

The `MAXPE` suffix allows keywords to control a mechanism's maximum allowed position error. When a maximum position error value is exceeded a motor will stall.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

As of November 2000, the `MAXPE` keywords are write-only and invoke either the `sliderDynamics()` function or the `wheelDynamics()` function, within `sliders.c` and `wheels.c`, as per the mechanism type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderDynamics or wheelDynamics (sliders.c or wheels.c)
motorSetAcceleration -> motorCmd   (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.1.3.18 MAXPOS

The `MAXPOS` suffix provides for keywords to obtain the maximum position to which a mechanism can be commanded. The maximum positions are retained in the motor daemon and are read from a configuration file (refer to Section 2.2 "Configuration file format (nirc2_motor.config)").

The `MAXPOS` keywords are read-only and invoke either the `sliderRequest()` function or the `wheelRequest()` function, within `sliders.c` and `wheels.c`, as per the mechanism type. The read calling sequence follows.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
```

4.1.3.19 MINPOS

The `MINPOS` suffix provides for keywords to obtain the minimum position to which a mechanism can be commanded. The minimum positions are retained in the motor daemon and are read from a configuration file (refer to Section 2.2).

The `MINPOS` keywords are read-only and invoke either the `sliderRequest()` function or the `wheelRequest()` function, within `sliders.c` and `wheels.c`, as per the mechanism type. The read calling sequence follows.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
```

4.1.3.20 MTR

The `MTR` suffix provides for keywords to return the mechanisms' associated motor numbers.

In actual fact, the MTR keywords can be written so as to change the number of a motor associated with a mechanism. This is a potentially dangerous thing to do! One may wish to do this to recover from a severe motor failure where a motor is swapped with a faulty one so as to provide some instrument functionality at the expense of some other functionality, or if a spare motor or motor memory is swapped with a faulty one on the instrument. In both these cases the motor number may not be the same as the original, in which case the MTR keywords would become useful. In all probability the MTR keywords will not exist in the default keyword configuration file and will only exist in an engineering mode.

Writing a MTR keyword will invoke either the sliderCommand() function or the wheelCommand() function within those same C modules. The write calling sequence follows.

Keyword library calling sequence:

```
keyword_write(keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
```

Reading a MTR keyword will invoke either the sliderRequest() function or the wheelRequest() function, within sliders.c and wheels.c, as per the mechanism type.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
```

4.1.3.21 NAME

The NAME suffix provides for keywords to drive mechanisms to positions that are specified by names that are read from configuration files (refer to Sections 4.5.3 "Wheel mechanisms' details files" and 4.5.4 "Slider mechanisms' details files") or to provide feedback about the mechanisms' current positions.

A mechanism's position names, ordinal position numbers, angular or distance positions, and encoder positions are all specified in the mechanism-details files. When a mechanism is moved via the setting of its NAME keyword, the corresponding encoder position is derived and the associated motor is commanded to that position. If an unknown name is specified then the motor is not moved and an error is returned.

The writing of a NAME keyword will cause the corresponding TARG, TRGT, and DEST keywords to be updated (refer to Sections 4.1.3.8 "DEST," 4.1.3.29 "TARG," and 4.1.3.30 "TRGT") and motor motion to be initiated. Once motor motion commences, reading a NAME keyword will provide values that reflect the mechanism's current position and not the values to which the NAME keyword was set. Thus, as the motor moves, the NAME keyword (as well as other motion feedback keywords) will be continually changing until motor motion stops. Assuming that the position is successfully attained, then the NAME keyword will again agree with the TARG keyword. As implied above, when a mechanism's NAME keyword is read, the current motor position is obtained from the motor and compared with the encoder positions associated with the position names. If a motor position does not correspond with a named position then "Unknown" is returned.

When a NAME keyword is written, either the moveSliderCmd() function or the moveWheelCmd() function, within sliders.c and wheels.c, is invoked as per the mechanism type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
moveSliderCmd or moveWheelCmd -> moveSlider or moveWheel
(sliders.c or wheels.c)
motorMove -> motorCmd  (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

When a NAME keyword is read, either the sliderPositionSts() function or the wheelPositionSts() function is invoked. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderPositionSts or wheelPositionSts -> updatePosnFeedback
(sliders.c or wheels.c)
motorTellPosition -> motorSts (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.1.3.22 NUM

The NUM suffix provides for keywords to either move a mechanism to an ordinal position or to provide feedback about a mechanism's current position.

A mechanism's position names, ordinal position numbers, angular or distance positions, and encoder positions are all specified in the mechanism-specific configuration files (refer to Sections 4.5.3 "Wheel mechanisms' details files" and 4.5.4 "Slider mechanisms' details files"). When a mechanism is moved via the setting of its NUM keyword, the corresponding encoder position is derived and the associated motor is commanded to that position. If an out-of-range position number is specified then the motor is not moved and an error is returned.

Writing to a NUM keyword, with an in-range value, will initiate motor motion. Once motor motion commences, reading the NUM keyword will provide values that reflect the mechanism's current position and not the values to which the keyword was set. Thus, as the motors move, the NUM keyword will be

continually changing until motor motion stops, such that most of the time the NUM keyword will have a value of –1 as it will be between discrete positions.

As implied above, when a mechanism's NUM keyword is read, the current motor position is obtained from the motor and compared with the encoder positions associated with the ordinal position numbers. If a motor position does not correspond with an ordinal position number then -1 is returned.

When a NUM keyword is written, either the moveSliderCmd() function or the moveWheelCmd() function, within sliders.c and wheels.c, is invoked as per the mechanism type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
moveSliderCmd or moveWheelCmd -> moveSlider or moveWheel
(sliders.c or wheels.c)
motorMove -> motorCmd  (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

When a NUM keyword is read, either the sliderPositionSts() function or the wheelPositionSts() function is invoked. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderPositionSts or wheelPositionSts -> updatePosnFeedback
(sliders.c or wheels.c)
motorTellPosition -> motorSts (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.1.3.23 RAW

The RAW suffix provides for keywords to move mechanisms to absolute encoder positions and/or provide feedback as to the mechanisms' current encoder positions.

The writing of a RAW keyword will cause the corresponding TARG and DEST keywords to be updated (refer to Sections 4.1.3.8 " and 4.1.3.29) and motor motion to be initiated. Once motor motion commences, reading a RAW keyword will provide values that reflect the mechanism's current position and not the values to which the RAW keyword was set. Thus, as the motor moves, the RAW keyword (as

well as other motion feedback keywords) will be continually changing until motor motion stops. Assuming that the position is successfully attained, the RAW keyword will again agree with the DEST keyword.

As implied above, when a mechanism's RAW keyword is read, the current motor position is obtained from the motor and compared with the encoder positions associated with the position names.

When a RAW keyword is written, either the moveSliderCmd() function or the moveWheelCmd() function, within sliders.c and wheels.c, is invoked as per the mechanism type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
moveSliderCmd or moveWheelCmd -> moveSlider or moveWheel
(sliders.c or wheels.c)
motorMove -> motorCmd  (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

When a RAW keyword is read, either the sliderPositionSts() function or the wheelPositionSts() function is invoked. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderPositionSts or wheelPositionSts -> updatePosnFeedback
(sliders.c or wheels.c)
motorTellPosition -> motorSts (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.1.3.24 RDY

The RDY suffix provides for keywords which indicate whether or not a mechanism is in a ready state, where that state is defined to be true when the current motor position agrees with the last demanded motor position and the motor is idle.

The RDY keywords are read only and invoke either sliderRequest() or wheelRequest(), within sliders.c and wheels.c, as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.1.3.25 RESET

The `RESET` suffix provides for keywords to perform software resets on mechanisms' motors.

Once a software reset has been performed it is impudent upon the user to perform a motor initialization and homing prior to attempting to move the motor.

The `RESET` keywords are write-only and invoke either `sliderCommand()` or `wheelCommand()`, within `sliders.c` and `wheels.c`, as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
motorReset -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.1.3.26 SIM

The `SIM` prefix provides for keywords to enable and disable motor simulate.

When simulation is enabled, commands are not sent to the associated motor, instead a set of motor controller-specific simulation functions are invoked within the motor daemon (refer to Section 6.4 "Motor simulation within the motor daemon"). The intent is to test and debug scripts and keyword library enhancements without interfacing to the actual motors.

Setting a `SIM` keyword to 1 will enable simulation for the underlying motor, and setting the keyword to 0 will disable simulation. When written to a `SIM` keyword will invoke either `sliderCommand()` or `wheelCommand()`, within `sliders.c` and `wheels.c`, as per the mechanism type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write(keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
```

```
motorSimulate (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

Reading a SIM keyword will return the current state of motor simulation and invokes either sliderRequest() or wheelRequest() as per the mechanism type. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.1.3.27 STAT

The STAT suffix provides for keywords which generate feedback on mechanisms' current control statuses.

The STAT keywords are read-only and are automatically updated in response to modification of various other keywords, motor motion, and motor faults. During normal operating conditions the mechanisms' statuses will transit from idle to moving, then back to idle. However, other states can occur, several of which indicate various fault conditions (timeout, fault, comms_flt, pos_limit_flt, neg_limit_flt, overtemp_flt, stall_flt, and position_flt) and, in addition, the states will reflect other motor functions (initing, homing, resetting, stopping, and killing).

The STAT keywords are read-only and invoke either sliderPositionSts() or wheelPositionSts(), within sliders.c and wheels.c, as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderPositionSts or wheelPositionSts (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.1.3.28 STOP

The STOP suffix provides for keywords to stopping mechanisms' motors.

In practice these keywords do not behave as expected. All motor motions are performed by invoking subroutines, which are stored in the motor controllers' non-volatile memories (refer to Section 9 "Animatics Motor Controllers"), in most cases, the subroutines perform two moves so as to compensate for backlash, and there is no mechanism for terminating a subroutine that is executing, short of a software reset. As a result, a STOP will usually occur before the backlash move, thus, only the "slew" will be killed and the backlash move will still occur. The command may have to be issued at least twice in succession, although the backlash move is so quick that it usually cannot be prevented.

The STOP keywords are write-only and invoke either the sliderCommand() function or the wheelCommand() function, within sliders.c and wheels.c, as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
stopMechanism (mechanisms.c)
motorStop -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.1.3.29 TARG

The TARG suffix provides for keywords to drive a mechanism to a named position. This is very similar to the behavior of NAME keywords except that TARG keywords do not change while the mechanisms are moving. The TARG keywords will be automatically set whenever motion commences, in response to the writing of the keyword, which causes motor motion, but they will not be altered during the motion. This also implies that reading TARG keywords return the last values to which they were set and does not involve reading the current motor positions.

A mechanism's position names, ordinal position numbers, angular or distance positions, and encoder positions are all specified in the mechanism-specific configuration files (refer to Sections 4.5.3 "Wheel mechanisms' details files" and 4.5.4 "Slider mechanisms' details files"). When a mechanism is moved via the setting of its TARG keyword, the corresponding encoder position is derived and the associated motor is commanded to that position. If an unknown name is specified, then the motor is not moved and an error is returned.

The writing of a TARG keyword will cause the corresponding TRGT and DEST keywords to be updated (refer to Sections 4.1.3.8 and 4.1.3.30) and motor motion to be initiated.

When a mechanism's TARG keyword is read the returned value is the last value to which it was set, which may be "Unknown."

When a TARG keyword is written, either the moveSliderCmd() function or the moveWheelCmd() function, within sliders.c and wheels.c, is invoked as per the mechanism type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
moveSliderCmd or moveWheelCmd -> moveSlider or moveWheel
(sliders.c or wheels.c)
motorMove -> motorCmd  (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

When a Read keyword is read, either the sliderRequest() function or the wheelRequest() function is invoked. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.1.3.30 TRGT

The TRGT suffix provides for keywords to read back the named positions at which the mechanisms' are positioned. These composite keywords are read-only and return values (named positions) that are derived from the mechanisms' current motor positions in encoder counts. The returned positions are derived from the information that is extracted out of the mechanisms' configuration files (refer to Sections 4.5.3 "Wheel mechanisms' details files" and 4.5.4 "Slider mechanisms' details files") and which associates position names with encoder positions, ordinal positions, and positioning accuracy.

When a TRGT keyword is read either a sliderRequest() or wheelRequest() function is invoked, as per the mechanism type. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.1.3.31 TYPE

The `TYPE` suffix provides for keywords, which return the mechanisms' types (slider or wheel). The intent is to provide information user interfaces can use for self-configuration.

The `TYPE` keywords are read-only and invoke either `sliderInfoFn()` or `wheelInfoFn()`, within in `sliders.c` and `wheels.c`, as per the mechanism type. The calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderInfoFn or wheelInfoFn (sliders.c or wheels.c)
```

4.1.3.32 VEL

The `VEL` suffix refers to a mechanism's maximum motor velocity parameter. As of November 2000, this is a write-only operation.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

Writing to a velocity keyword will invoke either `sliderDynamics()` within `sliders.c` or `wheelDynamics` within `wheels.c`, as per the keyword type which is implied by the keyword prefix. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderDynamics or wheelDynamics (sliders.c or wheels.c)
motorSetVelocity -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.1.3.33 VAR1

The `VAR1` suffix provides for keywords, which can be used by keyword clients to store and retrieve information of their choosing. The resulting keywords are identical to "user" variables (refer to Section 4.4 "User keywords").

The keyword values are stored in a hash table in the motor daemon, hence, they have persistence between invocations of the keyword library. Of course, the values will be destroyed if the motor daemon is restarted.

Writing a VAR keyword invokes either `sliderCommand()` or `wheelCommand()` within `sliders.c` or `wheels.c`, as per the keyword type. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
sliderCommand or wheelCommand (sliders.c or wheels.c)
setMotorProp (motor.c)
setmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
setmotorprop_1 (clientFuncs.c)
propSetString (properties.c)
```

Reading a VAR keyword will invoke either `sliderRequest()` or `wheelRequest()`, within `sliders.c` and `wheels.c`, as per the keyword type. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
sliderRequest or wheelRequest (sliders.c or wheels.c)
getMotorProp(motor.c)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.1.4 Miscellaneous mechanism keywords

Another small category of keywords exists, which is composed of a few miscellaneous keywords not associated with specific mechanisms. These keywords are essentially hard-coded within the C modules and are not a composite of prefixes and suffixes.

4.1.4.1 MOTORLIST

`MOTORLIST` is a read-only keyword, which returns a list of the motor numbers. The list is returned in the same order as the mechanism prefixes returned by `MECHLIST`. The intent is that a user interface can obtain as much information from keywords as is necessary to self-configure itself for controlling the instrument.

This keyword has aliases of `MOTLIST` and `MTRLIST`.

When the `motor-list` keyword is read a call is made to `findMechanisms()` within `mechanisms.c`. The calling sequences follow.

The keyword library calling sequence is:

```
keyword_read (keyword.c)
findMechanisms (mechanisms.c)
```

```
sliderList (sliders.c) and wheelList (wheels.c)
```

4.1.4.2 MECHLIST

`MECHLIST` is a read-only keyword, which returns a list of the mechanism prefixes. The list is returned in the same order as the motor number list returned by `MTRLIST`. The intent is that a user interface can obtain as much information from keywords as is necessary to self configure itself for controlling the instrument.

When the mechanism-list keyword is read a call is made to `findMechanisms()` within `mechanisms.c`. The calling sequences follow.

The keyword library calling sequence is:

```
keyword_read (keyword.c)
findMechanisms (mechanisms.c)
sliderList (sliders.c) and wheelList (wheels.c)
```

4.1.5 Adding new mechanism functions (suffixes)

The possibility exists that some day new mechanism functions will be required which would probably entail adding new keyword suffixes as well. Although this is a non-trivial procedure, it is well within the capabilities of most C programmers.

To add a new mechanism function that does not require a new motor function, one would need to modify `sliders.c` and/or `wheels.c`, depending on whether the new function is applied to slider or wheel mechanisms or both. One would need to add a new entry to SliderTable and/or WheelTable.

A new table entry requires the suffix string, a write function, and a read function. In most cases one of the existing read and write functions is sufficient, and one can modify those functions so as to include a case for the new suffix. If the new mechanism operation requires more than a few lines of code, then a new C function should be written and called from the new case statement. All that remains to be done is to add new keywords to `nirc2_config_file`.

As an example, let's add a command to cause a motor to release its brakes and disable its servo. This would allow someone to turn the motor shaft by hand. We will use "FREE" as the new suffix.

So we would add an entry to SliderTable after `BRAKES`:

```
Static SLIDER_KEYWORD_TABLE SliderTable[] = {

    {DIST, moveSliderCmd, sliderPositionSts},

    {NAME, moveSliderCmd, sliderPositionSts},

        .

        .

        .
```

```
        {BRAKES, sliderCommand, NULL},
        {"FREE", sliderCommand, NULL},
                .
                .
                .
        {MAXPOS, NULL, sliderRequest},
        {NULL, NULL, NULL}
    }
```

Now it is necessary to add a new case statement to `sliderCommand()`. To simplify this example we will assume that the motor is stopped and we will not check return statuses:

```
    } else if ( strstr( keywordSuffix, "FREE" ) ) {
        ret = motorBrakes( motor, 0 );
        sleep(2);
        ret = motorPower( motor, 0 );
    } . . .
```

To make this work for wheel mechanisms we would have to make the analogous changes in `wheels.c`.

The next step is to compile and link. The keyword library then adds the keyword in the configuration file. To make a keyword to free the camera we would simply copy an existing line in `nirc2_config_file`, say the line for `CAMENABLE`, then change the keyword (`CAMFREE`) and description. A modify command will now work with `CAMFREE`. However, we did not allow the user to undo the free command, that exercise is left to the reader.

4.2 Motor keywords

A set of keywords exists which allows direct control over motor functions. These operate at a level below the instrument mechanism keywords in that such things as engineering units, discrete positions and names are disregarded. This category of keywords is considered an engineering level, in most cases, such that the keywords may not exist in the operational `nirc2_config_file`.

The type of a motor keyword must be specified, in `nirc2_config_file`, as `MOTOR`.

Two main classes of motor keywords exist, generic and motor-specific. A small category of miscellaneous motor keywords is also described in a subsequent subsection.

4.2.1 Generic motor keywords

The generic motor keywords are those where the keywords imply the desired motor functions (such as `MTRSTOP`).

Generic motor keywords are all write-only and take a motor number as a parameter.

For all the generic motor keywords, a value of 0 is valid, even though no motor number 0 exists. When 0 is specified, the command is performed on all motors. Thus, the command "`modify -s nirc2m mtrhome=0`" would cause all motors to perform their homing sequence, whereas "`modify - s nirc2m mtrhome=1`" would cause only motor 1 to home. In the case of `MTRINFO` and `MTRPOSN`, a value of 0 results in a multi-line response, which may prove problematic for client programs.

Of the generic motor keywords, `MTRHOME`, `MTRKILL` or `MTRABORT`, and `MTRSTOP` or `MTRHALT`, are affected by the nowait option of the modify command. The default is wait, such that the keyword library waits until homing is complete or a motor stops moving. These waits have timeouts, which are specified in `nirc2_mechanism.config` (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)"). To cause one of these commands to terminate without waiting, one would use the `modify nowait` option (e.g., `modify -s nirc2m mtrstop=1 nowait`).

The generic motor keywords all take a motor number as a value, therefore, motor functions which are Boolean in nature must be implemented with two keywords. For instance, to enable a motor one would use `MTRENABLE` and to disable that same motor one would use `MTRDISABLE` ("`modify –s nirc2 mtrenable=3`" and "`modify –s nirc2 mtrdisable=3″).`

The behavior of the generic motor keywords is described in subsequent sections.

4.2.1.1 MTRABORT and MTRKILL

The abort keyword is intended to abruptly stop a motor.

In practice these keywords do not behave as expected. All motor motions are performed by invoking subroutines which are stored in the motor controllers' non-volatile memories, in most cases, the subroutines perform two moves so as to compensate for backlash, and there is no mechanism for terminating a subroutine that is executing, short of a software reset. As a result, an abort will usually occur before the backlash move, thus only the "slew" will be killed and the backlash move will still occur.

If a true kill is needed then the user should cause a software reset to occur (refer to Section 4.1.3.25 "RESET").

The abort keyword invokes `cmdMotor()` within `motorKeyword.c` which, in turn, invokes `motorKill()` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
```

```
motorKill -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.2 MTRBRAKESON and MTRBRAKESOFF

These keywords all control motor brakes where setting the brakes off will release the brakes and setting the brakes on will set the brakes. This may be desirable during troubleshooting to allow someone to rotate a motor shaft by hand.

These keyword invoke `cmdMotor()` within `motorKeyword.c` which, in turn, invokes `motorBrakes()` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorBrakes -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.3 MTRENABLE (MTRON) and MTRDISABLE (MTROFF)

The keywords allow one to enable and disable motors. Enabling a motor means that the motor is energized and the motor servo is running, and disabling is the converse. One may need to do this during troubleshooting.

These keywords invoke the `cmdMotor()` function within `motorKeyword.c` which, in turn, invoke `motorPower()` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorPower -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.4 MTRECHOON and MTRECHOOFF

These keywords allow one to enable and disable motors' echo modes. When in echo mode a motor will echo all commands received. This functionality has not been completely tested within the functions of `animatics.c` and its use is discouraged when the motor is connected to the motor daemon. However, this mode may be useful for troubleshooting when a motor is connected to a telnet session or a direct serial link.

These keywords invoke the `cmdMotor()` function within `motorKeyword.c` which, in turn, invokes `motorSetEchoMode()` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorSetEchoMode -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.5 MTRHALT and MTRSTOP

These keywords are intended to allow one to decelerate a motor to a stop; however, in practice this does not behave as expected. All motor motions are performed by invoking subroutines which are stored in the motor controllers' non-volatile memories, in most cases, the subroutines perform two moves so as to compensate for backlash, and there is no mechanism for terminating a subroutine that is executing, short of a software reset. As a result, a stop will usually occur before the backlash move, thus, only the "slew" will be killed and the backlash move will still occur. One could attempt repeated stop commands, but the backlash move is sufficiently short that it will most likely always occur.

These keywords invoke the `cmdMotor()` function within `motorKeyword.c` which, in turn, invokes `motorStop()` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorStop -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.6 MTRHOME

The home keyword allows one to cause motors to execute their homing procedures.

This keyword invokes the `homeMotor()` function within `motorKeywords.c` which, in turn, invokes `motorHome()` within `motor.c`. The `homeMotor()` function is relatively complex as it must keep track of which motors have started and/or complete homing when all motors are homed simultaneously, so please refer to the functional descriptions. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
homeMotor (motorKeyword.c)
motorHome -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.7 MTRINFO

The information keyword allows one to obtain basic information about one or all motors. The information returned consists of: the major-motor number (refer to Section 2.2.2 "Motor specifications"), the motor address and the motor type (Animatics in this case).

The calling sequence for the information keyword follows.

The keyword library calling sequence:

```
keyword_read (keyword.c)
showMotorInfo (motorKeyword.c)
motorInfo (motor.c)
motorinfo_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorinfo_1 (clientFuncs.c)
```

4.2.1.8 MTRIDLE

The motor idle status keyword provides feedback on the idle state of one or all motors. If the idle status for a single motor is requested then the returned value is either 1 (idle) or 0 (not idle). If the idle status for all motors is requested then the returned value is a bit mask where each bit is the state of a single motor (bit 0 should be ignored).

The calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
motionState (motorKeyword.c)
```

```
motorIsIdle -> motorCmd (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.2.1.9 MTRINIT

The motor initialize keyword provides a means of initializing one or all motors simultaneously.

This keyword invokes the `cmdMotor()` function within `motorKeyword.c` which, in turn, invokes `motorStop()` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorInitialize -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.10 MTRPWRON and MTRPWROFF

These keywords allow one to enable and disable one or all motors (powered up or servo enabled).

These keywords invoke the `cmdMotor()` function within `motorKeyword.c` which, in turn, invokes `motorPower()` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorPower -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.11 MTRRESET

These keywords allow one to cause one or all motors to execute their software.

These keywords invoke the `cmdMotor()` function within `motorKeyword.c` which, in turn, invokes `motorReset()` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorReset -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.1.12 MTRSIM

The simulation keyword allows enabling motor simulation for all motors (this cannot be done on an individual motor basis). When simulation is enabled, the motor daemon does not perform serial communication transactions with the instrument motors, instead, a set of simulation functions is invoked. The simulation functions are found in `animaticsSim.c` and approximate the motor controller subroutines, as they existed in November of 2000, including accelerations and velocities, thereby giving realistic homing motion responses.

The simulation keyword invokes the `cmdMotor()` function within `motorKeyword.c` which, in turn, invokes `motorSimulate` within `motors.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorSimulate -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd (animatics.c)
```

4.2.1.13 MTRWAIT

The motor wait keyword will wait for one or all motors to attain their idle states. There is a hard-coded maximum amount of time that will be awaited (`MAX_MOVE_TIME` in `motorKeyword.c`). If idling does not occur within this time then a timeout error is returned.

This keyword invokes `waitMotorIdle` within `motorKeyword.c,` which, in turn, calls `motorIsIdle` within `motor.c`. The calling sequence follows.

Keyword library calling sequence:

```
keyword_write (keyword.c)
waitMotorIdle (motorKeyword.c)
```

```
motorIsIdle -> motorSts (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
Motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimaticsCmd -> sendCommand and getAnswer (animatics.c)
```

4.2.2 Motor-specific keywords

The motor-specific keywords are those in which the motor number is embedded in the keyword name. The general form is `MTR<motor number><suffix>`. An example would be "`modify -s nirc2m mtr1stop=1`." Note that any non-zero value will cause the desired operation although these keywords are typically Boolean.

Of the motor-specific keywords, `HOME`, `KILL` or `ABORT`, `STOP` or `HALT`, `DELTA` or `DEL`, and `RAW`, are affected by the `nowait` option of the modify command. The default is wait, such that the keyword library waits until homing is complete or a motor stops moving. The waits have timeouts that are specified in the `nirc2_mechanism.config` file (refer to Section 4.5.2).

To cause one of these commands to terminate without waiting one would use the modify "`nowait`" option (e.g., "`modify -s nirc2m mtr1stop=1 nowait`"). In addition, the keywords which cause motion, (`DELTA` or `DEL`, and `RAW`) are affected by the wait flag in that motion will not commence until the motor is idle (`wait`), or an error is returned (`nowait`) when the motor is not idling at the time of the command.

One of the major differences between the motor-specific keywords and the generic motor keywords is that the motor-specific keywords do not require the motor number as an argument (recall that the motor numbers are embedded in the motor-specific keyword names) so they can be read and written (where necessary) and two keywords are not needed for Boolean-type operations.

Some of the motor-specific keywords are read-only, some are write-only, and some are read/write. The descriptions and function calls for most of the motor-specific keywords are identical to those provided in the subsections for the generic motor keywords, therefore, the following subsections only pertain to those motor-specific keywords which either have no generic motor keyword counterpart and/or significantly differ from the generic motor keywords.

4.2.2.1 ACCEL

The `ACCEL` suffix refers to a motor's motor acceleration parameter. As of November 2000, this is a write-only operation.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

Writing to an acceleration keyword will invoke `cmdMotor()` within `motorKeyword.c`. The complete calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorSetAcceleration -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.2.2 AMPS or CURRENT

The `AMPS` suffix refers to a motor's maximum motor current parameter. As of November 2000, this is a write-only operation. This keyword has the alias `CURRENT.` As of the aforementioned date only the `AMPS` suffix is used in the configuration file.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

Writing to an amperage keyword will invoke `cmdMotor()` within `motorKeyword.c`. The calling sequences for writing an `AMPS` keyword follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorSetCurrent  -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.2.2.3 ASK

Not all Animatics motor-control commands have been implemented with keywords. To provide as much flexibility during troubleshooting `ASK` keywords were created. The `ASK` keywords allow a client to send any arbitrary request strings to the motors and await the replies.

The client is responsible for the syntax of the request strings, and, in fact, the strings must be valid within the Animatics command language, including case. The command string may include multiple motor commands in which case it must be enclosed in double quotes (e.g., to stop motor 1 and read its current position, `modify -s nirc2m mtr1tell="X RP"`), however, if the command string includes multiple queries, only the first response will be awaited and returned (the other responses will be discarded when the next command is sent on the related communication link).

The ASK keywords are write-only and the reply is simply written to standard output (there is no KTL "query" program). These keywords invoke `motorStsKw` within `motorKeyword.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
motorStsKw (motorKeyword.c)
askMotor (motor.c)
askmotor_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
askmotor_1 (clientFuncs.c)
askAnimatics -> procAnimatics (animatics.c)
sendCommand then getAnswer (animatics.c)
```

4.2.2.4 BLASH

The BLASH suffix refers to a motor's backlash offset. As of November 2000, this is a write-only operation.

The backlash offset is applied within the motor controllers' subroutines for motor moves (refer to Section 9.1 "Animatics motor programs"). Although this parameter is dynamically modifiable, the intent is that once instrumentation integration is complete this parameter will seldom, if ever, be changed.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

Writing to a backlash keyword will invoke `cmdMotor` within `motorKeyword.c`. The calling sequences for writing a backlash keyword follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorSetBackLash -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand (animatics.c)
```

4.2.2.5 MAXPE

The MAXPE suffix allows keywords to control a motor's maximum allowed position error. When a maximum position error value is exceeded, a motor will stall.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

As of November 2000, the MAXPE keywords are write-only and invoke cmdMotor in motorKeyword.c. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorSetAcceleration -> motorCmd   (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.2.6 RAW

The RAW suffix provides for keywords to move motors to absolute encoder positions and/or provide feedback as to the motors' current encoder positions.

Motor motion is provided by a subroutine that is downloaded into the motor controller's non-volatile memory. The subroutine will automatically control the brakes and power, as well as, perform the backlash removal.

When a RAW keyword is written the moveMotor function within motorKeyword.c is invoked. This function will check whether or not the motor has been homed, and generate a message if it has not been homed, prior to moving the motor. The write calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
moveMotor (motorKeyword.c)
motorMove -> motorCmd  (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
animaticsCmd -> sendCommand  (animatics.c)
```

When a RAW keyword is read the getMotorPosition function within motorKeyword.c is invoked. The read calling sequences follow.

Keyword library calling sequence:

```
keyword_read (keyword.c)
getMotorPosition (motorKeyword.c)
motorTellPosition -> motorSTS (motor.c)
motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimatics -> sendCommand then getAnswer (animatics.c)
```

4.2.2.7 TELL

Not all Animatics motor control commands have been implemented with keywords. To provide as much flexibility as possible during troubleshooting `TELL` keywords were created. These keywords allow a client to send any arbitrary command strings to the motors.

The client is responsible for the syntax of the command strings, and, in fact, the strings must be valid within the Animatics command language, including case. The command string may include multiple motor commands in which case it must be enclosed in double quotes (e.g., to stop motor 1 and force its servo to turn off, `modify -s nirc2m mtr1tell="X E=0"`).

The `ASK` keywords are write-only and invoke `motorCmdKw` within `motorKeyword.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
motorCmdKw (motorKeyword.c)
tellMotor (motor.c)
tellmotor_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
tellmotor_1 (clientFuncs.c)
tellAnimatics -> sendCommand (animatics.c)
```

4.2.2.8 VEL

The `VEL` suffix refers to a motor's maximum motor velocity parameter. As of November 2000, this is a write-only operation.

Note that the non-operational keywords of this type may be removed from the default configuration file `nirc2_config_file` at some point.

Writing to a velocity keyword will invoke `cmdMotor` within `motorKeyword.c`. The calling sequences follow.

Keyword library calling sequence:

```
keyword_write (keyword.c)
cmdMotor (motorKeyword.c)
motorSetVelocity -> motorCmd (motor.c)
motorcmd_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
motorcmd_1 (clientFuncs.c)
```

```
animaticsCmd -> sendCommand  (animatics.c)
```

4.2.3 Miscellaneous motor keywords

A few miscellaneous keywords that do not fall into the categories of the generic motor keywords or motor-specific keywords are described in this section.

4.2.3.1 MTRDTEST and MTRMTEST

The test keywords were provided to facilitate timing tests. The keywords are write-only.

The `MTRDTEST` refers to a communications test with the motor daemon. The value to which the keyword is set specifies the number of times that a request is made to store a value in the hash table within the motor daemon. The total number of microseconds for the transactions is logged and printed to standard output. This test must be performed before the `MTRMTEST` (see the next paragraph for the explanation).

The `MTRMTEST` refers to a communications test with a specific motor, whose idle status is requested. The keyword must be set to the motor in question and the number of transactions is specified by the last value to which `MTRDTEST` was set (hence, the daemon test must precede the motor test). This test also logs and prints the total number of microseconds for the transactions.

Both tests have the same calling sequence as follows.

Keyword library calling sequence:

```
keyword_write (keyword.c)
commsTest (motorKeyword.c)
motorTest -> setMotorProp, or motorTest -> motorIsIdle -> motorSts
(motor.c)
setmotorprop_1 or motorsts_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence for `MTRDTEST`

```
setmotorprop_1 (clientFuncs.c)
propSetString (properties.c)
```

Motor daemon calling sequence for `MTRMTEST`

```
motorsts_1 (clientFuncs.c)
animaticsSts (animatics.c)
intRequest (connectFuncs.c)
procAnimatics -> sendCommand then getAnswer (animatics.c)
```

4.2.3.2 MTRDTRACE and MTRMTRACE

The `TRACE` keywords are provided to control the amount of information that is logged from within the motor daemon. In general, the amount of logged information increases with the size of the values to which these keywords are set.

The DTRACE keyword controls logging level from within the daemon functions other than the motor-specific functions (those in animatics.c), whereas, the MTRACE keyword controls the logging level from within the Animatics functions.

For a more complete description of the trace keyword behavior please refer to Section 2.3 "Logging and debugging." The calling sequences for both MTRDTRACE and MTRMTRACE are almost identical, as follows.

Keyword library calling sequence:

```
setTraceLevel (motorKeyword.c)
motorSetTraceLevel -> motorCmd (motor.c)
motorcmd_1 ( motor_clnt.c RPC)
```

Motor Daemon calling sequence:

`motorcmd_1 (client_funcs.c)` this is the end-point for daemon trace
`animaticsCmd (animatics.c)` this is the end-point for motor trace

4.2.3.3 LOCK and MASTER

The LOCK and MASTER are stored in the motor daemon hash table in a fashion similar to user keywords (refer to Section 4.4 "User keywords").

These keywords provide a client the capability to lock out all motor moves, which would typically be done while images are being taken with the detector. The MASTER keyword stores the identification of the client and allows only the process with that identification to lock and unlock the motors. When the "master" client terminates, the master keyword is set to –1, thereby allowing the next client to take control by setting the keyword to its process id.

4.3 I/O keywords

Several NIRC2 devices contain analog input/output signals and/or digital input/output signals.

I/O keywords differ from the mechanism and motor keywords in that the names may be any alphanumeric sequence, albeit without a leading numeric character. In addition, the I/O keywords' type fields are significantly different from all other keywords.

The I/O keyword type field in the nirc2_config_file must specify the signal type, device number, and signal number. Two forms of the type field exist:

```
<signal type>_C<device number>S<signal number>
<signal type>_C<device number>G<signal number>
```

The difference being that the "G" specifies a keyword associated with a gain term. The "G" form is only relevant to analog signals on analog devices, which provide for a dynamically controllable gain term.

The valid signal types are: `AIN_, AINRAW_, ADC_, ADCRAW_, AOUT_, AOUTRAW_, DAC_ or DACRAW_, DIN_, DOUT_, RELAY, SETPT`, or `TEMP`. Not all of these types are used in the NIRC2 system. The following subsections describe those types, which are used in the instrument.

The analog "`RAW`" types instruct the system (read I/O daemon) to return the data returned from the underlying device rather than any lookup table value (refer to Section 3.2.3.2 "Analog signal characteristics" for lookup table specifications).

The device number is the instrument-wide device number. Note that each device has a major and minor device number. This distinction exists because there are multiple communication links upon which multiple devices are connected, such that two modules may exist with the same address (one on each link). It is the instrument-wide device number (major), which must be embedded in an I/O keyword's type field.

The signal number is the channel number of that signal type on the specified device, commencing with the 0 or 1 as per the remote device nomenclature and in some cases the implementation of the device interface code within the motor daemon modules. In the case of a digital I/O device, whose channels are configurable, the number of input and output channels depends on the configuration, which must be specified in the appropriate record in `nirc2_io.config`.

4.3.1 Analog keywords

As mentioned above, the analog keywords are basically unrestricted in terms of their alphanumeric spelling. However, the type field is restricted and is used to identify signal type, device number, and signal number.

As a general rule, the I/O keyword names have spellings that are somewhat descriptive of the underlying signal so that an unfamiliar user could derive this from the names. For instance, `dettemp`, and `basetemp` could respectively refer to the detector and base temperatures.

The analog output keywords used in the NIRC2 system are:

`CH1SPD` is the single-stage cold head's speed control
`CH2SPD` is the dual-stage cold head's speed control

The calling sequences for the analog output keywords follow.

The keyword library calling sequences:

```
keyword_write (keyword.c)
irWrtDAC (analogKeyword.c)
ioDAwrite -> ioRequest (io.c)
iowrite_1 (io_clnt.c RPC)
```

The motor daemon calling sequences:

```
iowrite_1 (clientFuncs.c)
```

```
ioWrite -> wrtDac -> processCmd -> sendCmd then getAnswer (dgh.c)
```

The analog input keywords used in the NIRC2 system are:

CH1SPDRBV is the single-stage cold head's current speed (ReadBack Value)
CH2SPDRBV is the dual-stage cold head's current speed (ReadBack Value)

The calling sequences for the analog input keywords follow.

The keyword library calling sequences:

```
keyword_read (keyword.c)
irRdADC (analogKeyword.c)
ioADread -> ioRequest (io.c)
ioread_1 (io_clnt.c RPC)
```

The motor daemon calling sequences:

```
ioread_1 (clientFuncs.c)
ioRead -> rdAdc (dgh.c)
floatRequest (connectFuncs.c)
```

4.3.2 Digital keywords

As mentioned above, the digital keywords are basically unrestricted in terms of their alphanumeric spelling. However, the type field is restricted and is used to identify signal type, device number, and signal number.

Again, the keywords are essentially descriptive names.

The digital output keywords used in the NIRC2 system are:

ARGONPWR is the power control for the argon calibration lamp
CHREMOTE is the cold heads' remote control
CH1PWR is the single-stage cold head's power control
CH2PWR is the dual-stage cold head's power control
KRYPTONPWR is the power control for the krypton calibration lamp
LAMPPWR is the power control for the spectral lamp
NEONPWR is the power control for the neon calibration lamp
XENONPWR is the power control for the xenon calibration lamp

The calling sequences for the digital output keywords follow.

The keyword library calling sequences:

```
keyword_write (keyword.c)
irWrtDout (analogKeyword.c)
ioDOwriteChan -> ioRequest (io.c)
```

```
iowrite_1 (io_clnt.c RPC)
```

The motor daemon calling sequences:

```
iowrite_1 (clientFuncs.c)
ioWrite -> wrtDout -> processCmd -> sendCmd then getAnswer (dgh.c)
```

As of November 2000, there are no digital input keywords used in the NIRC2 system.

4.3.3 Set point keywords

The set point keyword type was created to differentiate between analog output signals and heater output controls. At first glance one would simply say they are both the same, however some devices (Lakeshore temperature controllers) require a different command string for heater set points than for analog outputs. Therefore, this category is needed so that software can determine which command to issue.

The Lakeshore set point keywords used with the NIRC2 instrument are:

`OPTBSTPT` is the optical bench temperature set point
`DETSTPT` is the detector head temperature set point

The keyword library calling sequence is:

```
keyword_write (keyword.c)
ioWriteKw (ioKeyword.c)
ioRequest (io.c)
iowrite_1 (io_clnt.c RPC)
```

The motor daemon calling sequences:

```
iowrite_1 (clientFuncs.c)
ioWrite -> wrtSetpoint -> sendCmd (lakeshore.c)
```

4.3.4 Temperature keywords

The temperature keyword type was created to differentiate between analog input signals and thermal inputs. At first glance one would simply say they are both the same, however, some devices (Lakeshore temperature controllers) require a different command string for temperature inputs than for analog inputs. Therefore, this category is needed so that software can determine which command to issue.

The Lakeshore temperature keywords used with the NIRC2 instrument are:

`TCAMERA` is the camera temperature
`THEAD1` is the single-stage coldhead temperature
`TBENCH` is the optical bench temperature
`THEAD2HI` is the dual-stage cold head's high temperature
`TSHIELD` is the shield temperature
`TDETBLCK` is the detector block temperature

`TEMPDET` is the detector temperature
`TGETTER` is the getter temperature
`THEAD2LO` is the dual-stage cold head's low temperature
`TCOLL` is the collimator temperature

The keyword library calling sequence is:

```
keyword_read (keyword.c)
ioReadKw (ioKeyword.c)
ioRequest (io.c)
ioread_1 (io_clnt.c RPC)
```

The motor daemon calling sequences:

```
ioread_1 (clientFuncs.c)
ioRead -> rdTemp (lakeshore.c)
floatRequest (connectFuncs.c)
```

4.4 User keywords

In addition to mechanism, motor, or I/O signal specific keywords, it is possible to create keywords that are more or less user variables. Said keywords are actually name/value pairs that are stored as strings in a hash table within the motor daemon.

The restrictions on user keywords are that the type field, in `nirc2_config_file`, must be `MOTOR, USER, CACHE, SLIDER`, or `WHEEL` and that one must not use any of the motor-specific suffixes in the keyword name (refer to Section 4.2.2 "Motor-specific keywords").

Use of user keywords allows one to read and write keywords that retain their values between keyword library invocations. This can be useful for holding state information for use between multiple scripts or for clients, which are active for only short periods of time. Of course all persistence is lost whenever the motor daemon terminates. As of November 2000, there is no mechanism for storing the motor daemon's hash table values in a file, although this would, in principle, be relatively simple to do.

The intention is that the instrument specialist is responsible for configuring user keywords, and that the user community will never modify the configuration files.

The user keywords are not described herein as the list is not and may never be constant.

As previously stated, the user keywords must exist in `nirc2_config_file`, in addition, initial values can be specified for the user keywords by adding appropriate lines in the `nirc2_motor_defaults_script` file. This file is loaded when the motor daemon starts. Adding the initial values is advisable so that clients who attempt to read the user keywords, prior to them being set by some other client, will not get errors.

The calling sequence for writing user keywords depends somewhat on the type assigned to the keywords within the `nirc2_config_file`, as each of `SLIDER, WHEEL`, and `MOTOR` keywords will pass through a different module after the `keyword_write` call within `keyword.c`.

The keyword library calling sequence is:

```
keyword_write (keyword.c)
sliderCommand (sliders.c for SLIDER)
or
wheelCommand (wheels.c for WHEEL)
or
setMotorPropKw (motorKeyword.c for motorKeyword.c)
setMotorProp (motor.c in all cases)
setmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
setmotorprop_1 (clientFuncs.c)
propSetString (properties.c)
```

The calling sequence for reading user keywords also depends somewhat on the type assigned to the keywords.

The keyword library calling sequence is:

```
keyword_read (keyword.c)
sliderRequest (sliders.c for SLIDER)
or
wheelRequest (wheels.c for WHEEL)
or
getMotorPropKw (motorKeyword.c for motorKeyword.c)
getMotorProp (motor.c in all cases)
getmotorprop_1 (motor_clnt.c RPC)
```

Motor daemon calling sequence:

```
getmotorprop_1 (clientFuncs.c)
propGetString (properties.c)
```

4.5 Configuration Files

The keyword library is driven by a set of configuration files, which are read when the `keyword_open` function is invoked from the KTL software layer. These configuration files specify which keywords are valid, which mechanisms exist, the characteristics of those mechanisms and how they relate to the motor and I/O devices.

Two configuration files must exist: `nirc2_config_file` and `nirc2_mechanisms.config`. There is some control over the explicit files used with the environment variables

NIRC2_CONFIG_FILE and NIRC2_MECHANISM_CONFIG, such that one could cause alternate files to be loaded for any given keyword library instantiation (perhaps for debugging or testing).

4.5.1 Nirc2_config_file (keyword characteristics)

The nirc2_config_file enumerates the available keywords and specifies the characteristics of those keywords. If a keyword is to be available to the user community (read Keck Tasking Library software), such that it can be operated on by show, xshow, and modify, then it must be listed in nirc2_config_file. The intent is that said file is maintained by the instrument specialists so as to provide the desired set of keywords to the user community.

Each entry in the nirc2_config_file must include various keyword characteristics. Most of the characteristics are required even though a few of them are not actually used by the keyword library. The characteristics are described in the following subsections in the order in which they must appear in the configuration file.

4.5.1.1 Keyword name

A keyword name is the string that clients will use when interfacing to the keyword library. A name may include any alphanumeric character as well as underscores, except that the leading character cannot be a number. Those keywords, which are included in image headers, are restricted to being only eight characters long as required by the FITS format.

Most keywords, which are associated with motor-driven mechanisms, must be spelled in specific ways as the software uses the name to determine what command to apply to which mechanism. These keywords can be viewed as composites of prefixes and suffixes, where the prefixes are specified in nirc2_mechanism.config (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)") and the suffixes are more or less hardcoded in the C modules.

4.5.1.2 Keyword description

A keyword description is a string that is displayed when one issues "show –s nirc2 keywords." The descriptions must be a single string (no spaces) consisting of any combination of alphanumeric characters as well as underscores.

4.5.1.3 Keyword save flag

The keyword save flag indicates whether or not the keyword is to be saved, each time it changes, by infoman. However, infoman is not used on the NIRC2 system. The save flags are essentially ignored, but they should be set to "F."

4.5.1.4 Keyword header flag

Each keyword has the potential of being included in the head of the image files. This is done via a one-shot procedure, which attempts to obtain all such keywords with a single call to the keyword library (a speed issue). The header flag indicates whether or not a keyword is to be included in the header list.

4.5.1.5 Keyword units

Some, but not all, keywords have some units. The keyword units are a single alphanumeric string that is displayed, along with a keyword's value, in response to a show command. Other keyword clients may obtain a keyword's units string via `keyword_ioctl()`.

4.5.1.6 Keyword data-type

A keyword data-type identifies the type of the keyword to KTL and, in most cases, to the functions in the keyword library. The data-type specifies how the KTL routines must parse the command arguments so that they can be correctly passed to the keyword library functions (i.e., the data-type is significant to the KTL->keyword library interface).

There are some NIRC2 keywords, which must be of specific types. This generally applies to string-typed keywords. The keyword library functions check the keyword data-types where necessary and reject those that are incorrect.

The keyword data-types are entered as strings: boolean, string, float, integer, and double.

4.5.1.7 Keyword class

The keyword class is essential as it defines the mechanism or device type to which the keyword is associated and, therefore, the processing performed by the keyword library.

The allowed mechanism classes are: wheel, slider, and motor.

The other device classes are pertinent to the analog and digital I/O signals, and temperature control and monitoring. Said classes commence with: `DIN, DOUT, AOUT, DAC, AIN`, or `ADC`. However, the class also must specify the device number and signal number. The general form of the class is `<signal type>_C<device number>S<signal number>`. Note the "`C`" is a hold over from other systems where the devices were referred to by "`Card number`." As an example, assume that I/O device number 1 is an analog output device, then a keyword attached to its output channel 0 would have a class type as follows, `AOUT_C1S0`.

4.5.1.8 Keyword I/O flag

The keyword I/O flags indicate whether a client is allowed to read and/or write specific keywords. In many cases this is superfluous as the keyword library functions allow some keywords to be read-only others to be write-only, however, the I/O flags do provide information to the users as documentation, if nothing else.

4.5.1.9 Keyword precision

Keyword precision is an optional keyword characteristic that indicates the number of significant decimal digits a keyword's value is valid. If used, this characteristic is entered in the configuration files as an integer value. Keyword clients can obtain a keyword's precision via `keyword_ioctl()`.

4.5.1.10 Keyword remark

A keyword remark is also an optional characteristic which can be an arbitrary string enclosed in double quotes. Note that there is no escape sequence for the double quote character itself, so it must not be embedded in the remark.

The parsing routines allow a remark to be 2048 characters long, but I suspect the UNIX file system will limit this to less.

A keyword's remark is obtainable via `keyword_ioctl()`.

4.5.2 Nirc2_mechanisms.config (mechanism characteristics)

The `nirc2_mechanisms.config` file provides information about the instrument mechanisms to the higher-level functions in the keyword library (`mechanisms.c`, `sliders.c`, and `wheels.c`). The configuration file is read and parsed when the keyword library is invoked.

Each line in the mechanisms' configuration file is pertinent to a specific NIRC2 motor-driven mechanism. One of the entries on each line is information depicting an additional configuration file that is specific to the mechanism in question. Please refer to Sections 4.5.3 "Wheel mechanisms' details files" and 4.5.4 "Slider mechanisms' details files" for a description of the mechanism-specific details files.

The expectations are that the `nirc2_mechanisms.config` file will only require modifications if testing with a subset of the instrument's mechanisms and/or, if a device fails during observing and a work around can be accomplished by reassigning devices.

The following subsections describe the entries of which a line in the mechanism configuration file is comprised, in the order in which they must exist on the line.

4.5.2.1 Mechanism type

The first entry on a mechanism configuration line must be the mechanism type. The type specifies whether a mechanism is a slider (a stage which linearly translated to discrete positions such as a slit mask) or a wheel (rotate to discrete positions such as a filter wheel). As of November 2000, the only values for the mechanism types are slider and wheel. Note that the shutter control is handled by the same keyword library functions as the sliders, so the shutter is marked as a slider.

The mechanism type actually determines whether the functions in `sliders.c` or `wheels.c` are used to process commands on the keywords, which are marked as `slider` and `wheel` in the `nirc2_config_file`.

4.5.2.2 Mechanism prefix

As should now be evident, the motor-driven-mechanism keywords can be visualized as a composite of a mechanism prefix and a functional suffix (for each mechanism there are over 30 such keywords). It is the mechanism prefixes in the mechanism configuration file which ties a set of keywords, which are specified in the keyword configuration file, to a specific mechanism and the corresponding functions which process commands for that mechanism.

The limitation on the length of the prefixes is defined by the FITS header file format, where a keyword must be eight or fewer characters. For NIRC2, the prefixes have been limited to three characters.

4.5.2.3 Motor number

Each mechanism has an associated motor, which drives that mechanism. The link between a motor and a mechanism is via the motor number specified on a mechanism configuration line. The motor number is passed to the motor daemon (refer to Section 2) along with commands to that motor.

The motor numbers must be unique for each mechanism and must cross-reference with the major-motor numbers specified in `nirc2_motor.config` (refer to Section 2.2 "Configuration file format"). These motor numbers are not the motor addresses, but are instrument-wide unique numbers.

4.5.2.4 Mechanism resolution

Mechanism resolution refers to the number of motor counts per unit of measurement of a mechanism. For sliders, the resolution would typically be encoder counts per millimeter, and for wheels the resolution would typically be encoder counts per 360 degrees of rotation of the mechanism (not the motor shaft).

This information is not hidden in the motor daemon so that limit checking can be performed on motor position demands prior to issuing RPC commands to a motor via the motor daemon.

The mechanism resolution is used by the functions in `sliders.c` and `wheels.c` when converting to and from engineering units in response to position keywords such as `camdist` and `fwiangl`.

4.5.2.5 Mechanism discrete position count

Each of the NIRC2 mechanisms, other than the pupil mask rotator, is typically positioned to one of several discrete positions. This information is used to create structures relevant to each mechanism within the `sliders.c` and `wheels.c` modules. The number of discrete positions is specified on a mechanism configuration line and must correspond to the number of entries in a given mechanisms' details files (refer to Sections 4.5.3 "Wheel mechanisms' details files" and 4.5.4 "Slider mechanisms' details files").

4.5.2.6 Homing timeout

A mechanism's homing timeout specifies the maximum time in seconds within which a mechanism should complete its homing routine. If a homing timeout is exceeded, a home command will abort and appropriate error messages will be logged and displayed.

4.5.2.7 Moving timeout

A mechanism's moving timeout specifies the maximum time in seconds within which a mechanism should complete any move. If a moving timeout is exceeded, a move will abort and appropriate error messages will be logged and displayed.

4.5.2.8 Mechanism details file environment variable

Each mechanism has an associated detail configuration file (refer to the next subsection). A UNIX environment variable exists for that configuration file, so that a different file can be used, perhaps for troubleshooting or to test updates.

The environment variables are specified as strings entered/spelled (include case) exactly as the associated UNIX environment variable.

4.5.2.9 Mechanism details file

As previously mentioned, each mechanism has an associated configuration file, which provides details about a mechanism's discrete positions (refer to Sections 4.5.3 "Wheel mechanisms' details files" and 4.5.4 "Slider mechanisms' details files"). The spelling of this characteristic must be exactly as that of the actual filename.

4.5.2.10 Mechanism description

An optional mechanism description is provided for in the `nirc2_mechanism.config` file. The description can be any arbitrary string enclosed in double quotes, albeit the double quote cannot be embedded in the description.

The description is returned with the `…DESCR` keywords (refer to Section 4.1.3.7) and is intended for use by graphical user interfaces.

4.5.3 Wheel mechanisms' details files

As mentioned in Section 4.5.2.9 "Mechanism details file," each slider and wheel configuration record, within `nirc2_mechanisms.config`, must specify a "details" file. The details files are read and parsed when the keyword library is activated and contain specifics about the discrete positions to which the mechanisms can be positioned, via the `NUM, DIST` or `ANGLE`, and NAME keyword (refer to Sections 4.1.3.9 "DIST or ANGL," 4.1.3.21 "NAME," and 4.1.3.22 "NUM").

The general form of a wheel-details file is:

```
FILTERTABLE = {
    <Name>, <Position #, <Motor position>, <Position accuracy>
    <Name>, <Position #, <Motor position>, <Position accuracy>
    <Name>, <Position #, <Motor position>, <Position accuracy>
    .
    .
    <Name>, <Position #, <Motor position>, <Position accuracy>
}
```

where:

The opening and closing braces are required;

The number of entries must correspond with the number of positions specified in `nirc2_mechanisms.config` (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)");

Name is an alphanumeric string enclosed in double quotes;

Position number is an integer corresponding to a discrete wheel position;

Motor position and Position accuracy can be either a floating value in millimeters or a motor position – in the case of NIRC2 it would be an integer in encoder counts – written as MM(<motor position>), where the parentheses are required.

4.5.4 Slider mechanisms' details files

As mentioned in Section 4.5.2.9 "Mechanism details file," each slider and wheel configuration record, within `nirc2_mechanisms.config`, must specify a "details" file. The details files are read and parsed when the keyword library is activated and contain specifics about the discrete positions to which the mechanisms can be positioned, via the `NUM, DIST` or `ANGLE`, and `NAME` keyword (refer to Sections 4.1.3.9 "DIST or ANGL," 4.1.3.21 "NAME," and 4.1.3.22 "NUM").

The general form of a slider-details file is:

SLIDERTABLE = {

<Name>, <Position #, <Motor position>, <Position accuracy>
<Name>, <Position #, <Motor position>, <Position accuracy>
<Name>, <Position #, <Motor position>, <Position accuracy>
.
.<Name>, <Position #, <Motor position>, <Position accuracy>

}

where:

The opening and closing braces are required;
The number of entries must correspond with the number of positions specified in nirc2_mechanisms.config (refer to Section 4.5.2 "Nirc2_mechanisms.config (mechanism characteristics)");

Name is an alphanumeric string enclosed in double quotes;

Position number is an integer corresponding to a discrete slider position;

Motor position and position accuracy can be either a floating value in millimeters or a motor position – in the case of NIRC2 it would be an integer in encoder counts – written as `MM(<motor position>)`, where the parentheses are required.

4.6 Asynchronous keyword updates (monitors and events)

The keyword library must support an event mechanism for those clients which have persistence, such as is required for `xshow` and graphical user interfaces. The intent is that if a user updates motor keywords with `modify`, or via scripts which use `modify`, or even from one or more user interfaces, then all persistent clients will see the changes.

The choice of the NIRC2 event notification implementation was somewhat influenced by the fact that the NIRC2 keyword library is not a server task. This simplifies the implementation of the event notification as the keyword library need never service more than one client and, hence, need not retain and manipulate a list of clients (show and modify clients terminate at completion of the command and persistent clients each have their own copy of the keyword library). Of course, this also means that notifying all persistent clients of updates is more complex than a simple broadcast to each client in a list.

When a client modifies a keyword, that keyword and its new value are written to a data file via a call to `errLog()`, which, as of November 2000, is implemented as a `syslog()` call. The advantage of this is that the UNIX `syslog` is a very stable and dependable utility. The logging uses `LOCAL1`, which must be set within the UNIX `syslog.conf` file. The keyword library defaults to a keyword log file of /var/log/local0, so to point the file to an alternate file the UNIX environment variable `KEYWORD_LOGFILE` must be appropriately set (as of November 2000, the file is nirc2info).

In order to obtain notifications of keyword changes, a persistent client must implement an event loop which includes performing `ioctl` calls (`keyword_ioctl()` within `keyword.c`) to specify read-continuous mode and to obtain a set of file descriptors upon which the client must pend (usually via a select() call). One should review `xshow` for a good example of how to implement the event loop. A similar technique is used in `ktcl` and `kidl`.

For NIRC2, the specifics of the implementation are that the read-continuous `ioctl` call will cause a child process to be forked which will write to a UNIX pipe every `HEARTBEAT_INTERVAL` (2 seconds). The pipe identification is returned to the client, via another `ioctl` call, for addition to the client's select list. Each time the child process wakes the parent (client) by writing to the pipe, the parent will call `keyword_event()` which in turn will call the functions in `extract.c` to parse the log file. The `keyword_event()` function will retain a pointer to the end of the log file such that it will start parsing at that point in the file upon the next wakeup.

4.7 Log files

Two forms of keyword library logging occur, both of which write to files via errlog calls. As of November 2000, errlog() has been implemented with the UNIX `syslog` facility.

Logging occurs whenever a keyword is modified, whether by client changes or automatically when motor conditions or positions change. This logging comprises the event notification as described in Section 4.6 "Asynchronous keyword updates (monitors and events)." This file is not intended to be

monitored by users. This file could be used by a future utility to restore the instrument context on software restarts.

The other category of logging also uses `errlog()` and generates an error log file that is intended for users to monitor via "`tlog`." This file is also monitored by tklogger so as to generate warnings when specific errors are detected (refer to Section 4.8 "Error notification"). The error log file also contains any errors that occur within the keyword library, keyword changes of those keywords that are deemed worthy of user attention (these are mainly relevant to mechanism position changes), and all information that is logged from the motor and I/O daemons (refer to Sections 2.3 and 3.3).

Both of the log files must be identified within the UNIX `syslog.conf` file, which is used by the `syslog` facility. As of November 2000, the error log file is `nirc2log` and the event log file is `nirc2info`.

The amount of detail, which is logged to the error log file, is somewhat controllable via the UNIX environment variable `LOG_UPTO.` This variable must be set within the context in which the client program is executed. For instance, if one was to use "`show`" and wants the log level increased to debug level, then they would need to "`setenv LOG_UPTO debug`" in the window in which the show is to be performed. For additional information on `syslog,` please refer to the UNIX documentation.

4.8 Error notification

As described in the various sections on logging (2.3, 3.3, and 4.7) the motor and I/O daemons, and keyword library modules all log errors to a file that is serviced by the UNIX `syslog` facility. This file is monitored and parsed by a `tcl` utility called `tklogger`.

4.8.1 tklogger

`Tklogger` is a `tcl` utility, which has a user interface, used to report errors to the NIRC2 instrument users.

`Tklogger` requires two files: a configuration file, `tklogger.config`, which identifies the files that are to be monitored and the colors used for reporting types of errors; and a procedures file, `.tklogger-procs`, which must exist in the root directory of the user account. The `procs` file contains the `tcl` procedures that are called upon the detection of specific error message; in general, the procedures generate the information that is displayed on the user interface.

Note that the `tklogger` user interface de-iconifies itself in an attempt to get the user's attention.

4.9 Building and releasing

The building of the keyword library uses the Keck general make facility. This facility reduces the amount of `makefile` drudgery that a programmer would otherwise need to be concerned with. For a description of the make facility please refer to *KSD 31 "/kroot Programming Manual."*

The basic recompilation command is simply "`gmake`." This will affect the sub tree in which the command is issued, but not the parent directories or release directories.

To recompile, link, and release the keyword library the command is "`gmake install`." This command will affect the entire keyword sub tree (/kroot/kss/nirc2/mech) as well as the release tree.

The release tree is /kroot/rel/default/… such that links are added to the subdirectories have include, lib, data, and bin when the "`gmake install`" processes. The actual released files, libraries, and executables are written to subdirectories of /kroot/rel/default/Versions/nirc2/mech/.

Below the mech release directory is a numeric subdirectory that corresponds to the current release version number as specified by the "`VERNUM`" statement in the `Makefile` within /kroot/kss/nirc2/mech. If a software specialist modifies any of the C modules used by the keyword library then that person is expected to change the `VERNUM` statement. Doing this will preserve the current released files so reverting can easily be accomplished, if needed. If `VERNUM` is not changed, the current release files will be overwritten when "`gmake install`" processes.

The software specialist is also expected to commit any changes with the appropriate CVS commands (refer to alternate documentation for CVS commands), including the modified Makefile.

Note that the files within /kroot/kss/ir_common and its subdirectories are used by the NIRC2 daemons and keyword library. If the files in `ir_common` are modified, then a build must be performed within that sub tree (refer to Sections 2.5 "Building and releasing" and 3.5 "Building and releasing") before building …/nirc2/mech.

5 Troubleshooting Guide

The main troubleshooting technique for the NIRC2 instrument is to enable various levels of information logging, all of which provide feedback in the error log file (refer to log file Sections 2.3 "Logging and debugging," 3.3 "Logging and debugging," and 4.7 "Log files") and/or statements printed within the user/client `sysout` context (for `show` and `modify` this would be the window in which the command is entered).

There is a UNIX environment variable to control the level of logging by the syslog daemon (refer to Section 4.7 "Log files").

There is a UNIX environment variable to control logging from within the keyword library, the motor daemon, and the I/O daemon.

There are keywords which control logging of information from within the motor daemon.

There are keywords for controlling logging of information from within the keyword library.

5.1 Environment variables to control logging

In addition to the UNIX environment variable `LOG_UPTO` (described in Section 4.7 "Log files") the variable `NIRC2_KEYWORD_DEBUG` can be set to enable messages which display the entry conditions of each of the keyword library interface functions within `keyword.c`. When said variable is set, each function call will cause a message to be printed to standard output. This provides a convenient trace when clients are being debugged as one can readily see whether it is an open, read, write, or `ioctl` call which generates a fault. Note that `keyword_ioctl()` will generate a message for most of the `ioctl` options that it processes.

If the aforementioned variable is set then the messages will be generated for all subsequent `show` and `modify` calls within that context (terminal session). If one needs to enable logging for a persistent client (`xshow`, `tcl` or `idl` user interface) then the variable must be set in the window within which the client is launched.

5.2 Keywords to control logging

There are NIRC2 keywords for controlling the logging of detailed information within the motor daemon and also within the highest level of keyword library modules. The keywords are stored within a hash table in the motor daemon so that they have persistence between activations of the keyword library.

The keywords, which affect logging in the motor daemon, are `MTRDTRACE` and `MTRMTRACE`. These keywords are described in Sections 2.3 "Logging and debugging" and 4.2.3.2 "MTRDTRACE and MTRMTRACE."

In addition, the following keywords can be used to enable logging from within various modules of the keyword library:

`NIRC2_MOTOR_DEBUG` provides a trace of the functions within `motor.c`.

`NIRC2_IO_DEBUG` provides a trace of the functions within `io.c`.

`NIRC2_MECHANISM_DEBUG` controls information from within `mechanisms.c` where the higher the value of the keyword the more detail that is generated, including the reading of the keyword configuration file.

`NIRC2_SLIDER_DEBUG` controls the information from within `sliders.c` where the keyword value controls the amount of detail.

`NIRC2_WHEEL_DEBUG` is analogous to the aforementioned slider debug keyword but is relevant to the functions in `wheels.c`.

6 Simulation

If one cannot diagnose a problem from either the error logs or by enabling debug statements (refer to Section 5 "Troubleshooting Guide"), then mechanism and/or motor simulation may provide the answer.

Three levels of simulation are provided, one at the mechanism level within the keyword library, one at the motor/device level within the keyword library, and one at the motor level within the motor daemon.

6.1 Mechanism simulation

Minimal simulation is provided in the keyword library at the mechanism level.

A SIM keyword is supported for each mechanism (e.g., `FWOSIM, FWISIM, CAMSIM`,...) the setting of which only affects motion commands. If a simulate keyword is set, then the writing of a motion keyword (`NAME, TARG, NUM, RAW`, and `DIST/ANGL` – refer to Section 4.1.3 "Mechanism operations relating to keyword suffixes") will cause the associated `TRGT, DEST`, and `STAT` keywords to be updated, but the motion command is not issued to the motor daemon and, hence, the mechanism does not move.

The `SIM` keywords exist for testing/debugging/troubleshooting and do not provide added value to operations. The use of the keywords may assist users when debugging shell scripts, that is, motors will appear to move, but the instrument is not physically affected.

6.2 Motor simulation within the keyword library

More extensive simulation is provided, at the motor level, within the keyword library. This simulation is controlled by a set of UNIX environment variables that affect the functions in `motor.c`. The environment variables are checked when `motorInit()` is called which occurs upon each keyword library activation.

The simulation, when enabled, affects all motor-controlled mechanisms, that is, one cannot enable simulation for one motor and not the others. Simulation affects the system such that commands are not forwarded to the motor daemon, and keyword reads (`show`) respond with the values of appropriate environment variables.

The original intent was to test all conditional branches and error log calls relevant to motor control and status within the keyword library (runtime segmentation faults occur for certain errors in `errlog()` parameters as the compiler does not detect the errors). Consequently, some functions in `motor.c` consist of more lines of code relevant to simulation than not and, in some cases, the functions in `motor.c` are hard to read and understand. The most complex of these are `motorCmd()` and `motorSts()` as they are used by most of the other functions within the module.

There are numerous UNIX environment variables for controlling simulation, many of which are used only within specific functions in `motor.c`. The variables allow one to run in simulation modes with or without the motor daemon, and with or without actual motors being connected. Other variables allow one to control specific return values for motor daemon RPC calls (in some cases the motor daemon return values are overwritten with the value of environment variables). With appropriate setting of the

variables, and use of `show` and `modify`, within UNIX shell scripts, one can create automated tests for the keyword library.

The environment variables are described in subsequent paragraphs in regards to their effect on the functions within `motor.c`.

When `motorInit()` processes it attempts to get 6 simulation-related environment variables. If any one of `NIRC2_MOTOR_SIM, NIRC2_MOTOR_DISCONNECTED`, and `NIRC2_MOTOR_NODAEMON` exist then the values of 17 other environment variables are obtained.

The 17 environment variables have three forms: `NIRC2_MOTOR_SIM_RETn`, `NIRC2_MOTOR_SIM_STSn`, and `NIRC2_MOTOR_SIM_MSGn`. Where "n" is an integer from 1 to 11. These variables allow one to control specific responses and success/failure statuses from motor commands, even when the motors are physically connected, as follows: variables of the form `…RETn` all refer to return values (success/failure status) from RPC calls; `…STSn` all refer to numeric responses to motor requests; and `…MSGn` all refer to string responses to motor requests.

There are 11 environment variable suffixes (1 to 11) as there are 11 functions within `motor.c` which perform RPC calls to the motor daemon. This allows one to explicitly control the behavior of each of those functions. The correlation between the numeric suffixes and the functions in `motor.c` in numeric order are: `setMotorProp(), getMotorProp(), motorExists(), motorCmd(), motorSts(), motorIsIdle(), waitForIdle(), tellMotor(), askMotor(), motorInfo()`, and `motorTellHomingStatus()`.

Note that there are 11 environment variables of the form `…RETn` but only a few of forms `…STSn` and `…MSGn` as only a few of the motor commands generate responses, but all of them generate a success/failure return value.

If `NIRC2_MOTOR_NODAEMON` is set then a connection is not made to the motor daemon, `setmotorprop()` returns the value of `NIRC2_MOTOR_SIM_RET2` (with a default of 1 for success), and `getmotorprop()` returns the value of `NIRC2_MOTOR_SIM_RET2` and the property value given by `NIRC2_MOTOR_SIM_MSG2`.

If `NIRC2_MOTOR_SIM` is set then all of the various response and return environment variables come into play within the associated functions in `motor.c` (as per the aforementioned relationships). In addition, simulation affects `waitForIdle()` by using the value of `NIRC2_MOTOR_SIM` as the timeout value, and the value of `NIRC2_MOTOR_SIM_RET7`, which should be a negative integer, is used to simulate a timeout after the number of calls to `waitForIdle()` given by the absolute value of the variable. Thus, one can simulate a timeout on a call to a specific motor.

Also, when `NIRC2_MOTOR_SIM` is set its value is used as the timeout value within `motorHome()` and `motorMove()`.

The environment variable NIRC2_MOTOR_DISCONNECTED modifies the behavior of the simulation environment variables by controlling when an error will be simulated. If this variable is set to a negative integer value then an error will be generated from the "nth" call to the functions within motor.c where "n" is the absolute value the variable. For example, if NIRC2_MOTOR_DISCONNECTED is set to –4 and the getMotorProp() function is called 5 times then the value from the motor daemon is returned for the first 4 calls and the value of NIRC2_MOTOR_SIM_MSG2 is returned on the 5 call. Thus, one can more or less simulate various motor and/or motor daemon errors from specific motors or motor operations. Note that "n" refers to the cumulative calls to all functions in motor.c, not an individual function, so one must be somewhat cognizant of the motor.c calls performed in response to show and modify of NIRC2 keywords, in order to get the desired simulated behavior.

The three remaining environment variables are NIRC2_MOTOR_SIM_EXISTS, NIRC2_MOTOR_SIM_ISIDLE, and NIRC2_MOTOR_SIM_ISHOME. As you probably surmised, these control the simulation from motorExists(), motorIsIdle(), and motorTellHomingSts(). The simulation within these functions is controlled via the corresponding environment variables and NIRC2_MOTOR_SIM. This was necessary so as to be able to test certain conditional branches within the mechanism modules (mechanisms.c, sliders.c, and wheels.c).

6.3 I/O device simulation within the keyword library

Simulation of the I/O devices (DGH and Lakeshore) is analogous to the motor simulation within the keyword library (refer to Section 6.2 "Motor simulation within the keyword library"). The main difference between the two is that I/O simulation only requires a single set of environment variables to control the functions in io.c, as opposed to the motor simulation, which requires a set of variables for each function within motor.c.

The set of environment variables to control simulation are: NIRC2_IO_SIM, NIRC2_IO_SIM_VAL, NIRC2_IO_SIM_STS, NIRC2_IO_SIM_MSG, NIRC2_IO_SIM_RET, NIRC2_IO_SIM _EXISTS, and NIRC2_IO_DISCONNECTED.

The variable NIRC2_IO_SIM _EXISTS only applies to ioBdExists() and is used independent of all other variables except NIRC2_IO_SIM_VAL. The value of NIRC2_IO_SIM_EXISTS is used to control fault simulation within the function.

If NIRC2_IO_SIM is set then the return values from the RPC calls within the function in io.c are controlled by the value of NIRC2_IO_SIM_RET, where different values allow simulating various faults. To understand how this affects a specific function one should review the functions themselves (ioAsk(), ioTell(), ioSetProp(), ioGetProp(), and ioRequest()).

The environment variable NIRC2_IO_DISCONNECTED allows one to control when a fault condition is simulated. The variable must be set to a negative value whose absolute value is the number of calls to the aforementioned functions that will succeed prior to a simulated fault. Note that number of successful calls is the total of all calls to all those functions not the number of calls to a single function.

6.4 Motor simulation within the motor daemon

Simulation has also been provided within the motor daemon. When motor simulation is enabled command transactions with the motor controllers terminate and instead the functions in `animaticsSim.c` are called.

The simulation is controlled by the keyword `MTRSIM` as described in Section 4.2.1.12 "MTRSIM." When enabled, simulation is performed for all motors, that is, simulation cannot be enabled on an individual motor basis. The intent is to provide a means of testing new software and/or user scripts without having motors physically connected.

The functions in `animaticsSim.c` approximate the motor controller subroutines, as they existed in November of 2000, including accelerations and velocities, thereby giving realistic homing and motion responses.

7 Pupil Mask Rotator

The pupil mask rotator is the only mechanism within the NIRC2 instrument that is singled out in this document because its control has been implemented differently from all the other NIRC2 mechanisms.

The pupil mask rotator differs from the other motor-controller mechanisms because it has a control mode whereby the mechanism must "track" the position of the telescope elevation angle and the adaptive optics image rotator.

The rotator control has been implemented as a separate process, which essentially monitors certain keywords and modifies the rotator's behavior in response to events on those keywords. This is, in effect, an evolution of the `watch_imrot` software used for the HIRES rotator control.

The rotator control software consists of a generic part and a specific part (analogous to the original `watch_imrot`). The generic code is found in /kroot/kss/ir_common/watch_rot/generic and the specific code is found in /kroot/kss/nirc2/mech/pmr/watch_rot/specific.

Note that the `watch_keyword` task does not have a keyword library or any keywords specific to itself. Any keywords that it monitors, even those used to control aspects of the task itself, must exist in some external keyword service. For instance, a keyword can be associated (refer to Section 7.1.2 "Configuration files") with `logLevel_cb()`, which one can then use to control the amount of information logged, by `log_info()` and `log_msg()` (all these functions are in `generic_callbacks.c` which is discussed below). If one is adapting this task to an instrument, which does not have the flexibility of user type keywords, then one could consider using the "cache" service (this will be described in a forthcoming KSD).

7.1 Generic (external keyword monitoring)

The generic code actually comprises the task (`watch_keywords`), which is launched for rotator control.

The generic code consists of two modules: `watch_keywords.c` that contains functions for configuration and initialization, as well as the main routine that detects and dispatches keyword events; and `generic_callbacks.c` that contains some logging routines and some event callback routines, which can be associated with specific keywords for any given keyword service.

The essence of the system is to be able to open any shareable library or keyword service and to cause specific functions, contained in the libraries, to be invoked in response to events on specific keywords. The opening of libraries and finding of functions in the symbol tables is done via use of dynamic linker routines (dlopen, dlsym, etc.).

The system must be given information about the libraries, services, keywords, and functions, and then call the appropriate KTL functions to configure the event handling, as discussed in Section 7.1.2.

7.1.1 Command line arguments and options

The `watch_keyword` task will open any number of shareable keyword libraries and any number of keyword services that are given to it as arguments (argv). The ordering of the command line arguments is not important.

The task uses a function called `lib_open()`, in `watch_keywords.c`, which has heuristics for locating the libraries it is directed to open, whereas the services are opened via `ktl_open()` and special processing is not required.

7.1.1.1 Shareable library specifications (the "-l" option)

To cause the task to open a shareable library one would precede the library name with "`-l`." The library name must not include the "`lib`" prefix nor the "`.so`…" suffix.

To load the pupil mask rotator function library (`librnirc2pmr.so.0.0`) the command would be "`watch_keywords –l nirc2pmr`."

7.1.1.2 Keyword service specifications (the "-s" option)

To cause the task to open a keyword library service one would precede the service name with "-s."

To load the NIRC2 motor keyword library (as needed for rotator control) the command would be "`watch_keywords –l nirc2pmr –s nirc2`."

7.1.1.3 Verbose mode (the "-v" option)

The "-v" command line option exists for displaying internal information when the `watch_keyword` task initializes. This would typically be done if things have gone awry. The displayed information will assist in determining the problem.

7.1.1.4 Interactive mode (the "-t" option)

The "`-t`" option exists to allow the user to determine whether or not functions were actually found and loaded. Again this is a debugging aid.

The system will prompt the user for the name of a function to find in the symbol table. However, one should be wary about executing a found function, as a segmentation fault will occur if the function has any calling arguments (there is no way to enter appropriate parameters).

To terminate interactive mode the user can type: `quit` (allows the task to continue); and `exit` (terminates the task).

7.1.2 Configuration files

The purpose of the configuration files is to associate specific keywords with specific C functions such that the task will cause those functions to be invoked when events occur on the associated keywords.

Once all libraries and services are opened the `watch_keyword` task attempts to find a configuration file for each of the services that were opened. Part of the heuristics for finding the files involves searching for a UNIX environment variable of the form `WATCH_<service>_KEYWORDS`, and when this fails a file of the form `watch_<service>_keywords.config` is expected to be found.

Each configuration file must consist of rows of two element pairs where the first element is a keyword and the second element is a function name. Any given specified function must exist in the symbol table, which implies it was loaded with one of the shareable libraries and/or services. Assuming a function is found then a call is made to `ktl_read()` to enable monitoring of the associated keyword and to associate the function with events on that keyword.

In addition to the event function, an additional argument is also passed to `ktl_read(),` which in turn is passed to the function when an event occurs. Said argument is intended to be a storage location for the function's use. Note that any given function may be associated with multiple keywords so this provides for data storage on a keyword-by-keyword basis, that is, we let KTL maintain a list for us.

There are restrictions on the event functions, as they must adhere to the interface expected by KTL. Four arguments are expected: (1) a character string, which will be the keyword itself; (2) a pointer to the aforementioned optional argument, which KTL treats as a void pointer; (3) a pointer to a KTL_POLYMORPH; and (4) a pointer to a KTL_CONTEXT (refer to the KTL documentation – KSD 8- to understand the relevant structures). Hence, one can only associate keywords to functions that have the aforementioned arguments and any other associations may cause indeterminate results including segmentation faults.

7.2 Specific (rotator control algorithms and functions)

The instrument-specific code provides the actions to be taken in response to events on one or more keywords. This could be any desired behavior, the only restriction is that the arguments to the top layer of functions must adhere to the KTL requirements as described in Section 7.1.2 "Configuration files."

In the case of NIRC2, the specific code comprises the pupil mask rotator control.

The main purpose of the rotator control software is to extrapolate the DCS demands for elevation and rotator so as to drive the rotator motor. The DCS demands are issued at a nominal rate of 2 Hz and are the positions at which the telescope and rotator are expected to be when they are issued; hence, the demands are historical when received by the rotator software.

The main functions of the rotator software are: to respond to configuration keywords in order to initialize data structures; to update data structures (nominally at 2 Hz) in response to events on the DCS elevation and rotator demand keywords; and to extrapolate the demands at a higher frequency (nominally at 4 Hz) so as to drive the rotator motor. A separate thread is created to handle the extrapolation and drive function, all other functions occur directly in response to keyword events as setup via the generic keyword watcher task (discussed in Section 7.1"Generic (external keyword monitoring)").

7.2.1 Configuration

An attempt was made to make the rotator servo as instrument-independent as possible. Consequently, numerous rotator keywords must exist in some keyword library service, and, they must be initialized to configure the rotator servo. When adapting this system to an instrument that does not have the flexibility of "user" keywords, one can utilize the "cache" service (to be described in a forthcoming KSD).

All of the configuration keywords must be initialized after each time the `watch_keyword` task is started (refer to Section 7.1"Generic (external keyword monitoring)"). If the task is restarted, then the configuration keywords must be set again as their context is lost when the task terminates. A script exists for configuring the rotator servo for the NIRC2 pupil mask rotator, namely, `setup_Pmr`.

Some of the configuration keywords have default values and only need to be modified if the default values are to be altered. Said keywords and their defaults are provided in Table 1.

Table 1. Configuration keywords and defaults.

Keyword	Description	Default
ROTBASE	base term (degrees) in the servo equation	0.0
ROTCOE	coefficient for the elevation term in the servo equation	1.0
ROTCOR	coefficient for the rotator term in the servo equation	1.0
ROTMAXA	maximum acceleration (degrees per second per second) between two successive	0.1

	demands above which a switch to slewing occurs; this has not been implemented as of March 2001	
ROTMAXSTEP	maximum allows displacement (degrees) between two successive demands above which a switch to slewing occurs; the tracking extrapolation information is reset as well	1.0
ROTMAXV	maximum allowed motor velocity in degrees; this is only used for adaptive velocity control, which has not been implemented as of March 2001	10.0
ROTMPCYCLES	number of servo cycles between fetches of motor feedback	0
ROTOFFSET	offset term (degrees) in the servo equation	0.0
ROTPERIOD	number of milliseconds between servo updates	500.0
ROTPSNLATE	maximum time in seconds between updates in DCS position demands, error warnings are issued if updates take greater than this time	3
ROTPSNTOUT	maximum time in seconds between updates in DCS position demands before tracking is disabled	180
ROTVSCALE	scale factor applied to velocity prior to outputting a velocity demand to the motor; this is only used for adaptive velocity control, which has not been implemented as of March 2001	1.0

There are a few keywords that specify control parameters and that must be initialized after each servo task restart. Said keywords are defined in Table 2.

Table 2. Control parameter keywords.

Keyword	Description	NIRC2 value
ROTINSTR	specifies the keyword library service associated with the instrument	nirc2
ROTPREFIX	specifies the prefix to the instrument's rotator keywords	pmr
ROTVSLEW	velocity value output to the rotator motor when slewing	150000
ROTVTRK	velocity value output to the rotator motor when tracking	4000

Additional keywords exist, which must also be set after the `watch_keyword` task is started and before the servo thread is launched. These keywords specify the instrument keywords and their command strings and/or values that are used by the rotator servo for the purpose of translating user requests into rotator motor demands. These keywords are defined in Table 3.

Table 3. Instrument keywords and command strings/values used by rotator servo.

Keyword	Description	NIRC2 value
ROTHLTFRMT	motor command string for halting the motor	END X UA=1 E=0 g=0
ROTHLTKW	keyword for issuing the halt command to the motor	`mtr7tell`
ROTMPFRMT	motor command string for prompting for motor position	RP

ROTMPKW	keyword for issuing motor position prompts	mtr7tell
ROTMPTYPE	type of the values returned from a motor position prompt	integer
ROTONFRMT	motor command string for enabling the motor (brakes off and power on)	UA=0 E=e
ROTONKW	keyword for issuing motor enable commands	mtr7tell
ROTSLWKW	instrument keyword for issuing slew demands	pmrangl
ROTSLWTYPE	data type associated with ROTSLWKW (pmrangl)	double
ROTSLWIUNITS	units associated with ROTSLEW	degrees
ROTSLWOUNITS	units associated with ROTSLWKW (pmrangl)	degrees
ROTTRKFRMT	motor command string for issuing tracking demands	P=%d G
ROTTRKKW	keyword for issuing tracking demands	mtr7tell
ROTTRKOUNITS	units associated with ROTTRKKW (mtr7tell)	counts
ROTTRKTYPE	data type of the tracking demands	integer
ROTVFRMT	motor command string for issuing velocity demands	V=%d G
ROTVKW	keyword for issuing velocity demands	mtr7tell
ROTVTYPE	data type of the velocity demands	integer

The reader may have noticed that several of the ROT…KW keywords are set to the NIRC2 motor control keyword mtr7tell. The mtr7tell keyword is a general-purpose keyword used to issue any arbitrary command to motor number 7, which happens to be the pupil mask rotator's motor number. The mtr7tell keyword is used rather than other NIRC2 keywords, which exist for the purpose of slewing and halting because those keywords have a built-in behavior that requires considerable communication with both the motor daemon and the motor controller. The duration of the extensive communication would perturb the rotator servo (keep in mind that communications with the motor controllers is via relatively slow serial links). The use of mtr7tell bypasses the higher level processing for more expedient transactions.

7.2.2 Control keywords

In addition to the configuration keywords, several keywords exist for controlling the rotator control task.

7.2.2.1 Keywords affecting the rotator positioning equation

The rotator positioning equation is given by:

```
ROTCOE * elevation + ROTCOR * rotator + ROTBASE + ROTOFFSET
```

The elevation and rotator keywords are specified in the DCS keyword configuration file as described in Section 7.1.2 "Configuration files."

The four keywords (ROTBASE, ROTOFFSET, ROTCOR, and ROTCOE) used for modifying the rotator positioning equation were discussed in Section 7.2.1 "Configuration," and are not expounded upon here other than to state that ROTBASE is used to register the pupil mask with the telescope pupil (a given spider orientation), and ROTOFFSET is used to accommodate displacements introduced by the AO k-mirror.

7.2.2.2 Starting the servo thread

Once the configuration keywords have been initialized (modified with KTL writes via the modify command) then the servo thread is started with the ROTSERVO keyword (`modify -s nirc2 rotservo=1`). Once the servo is started the DCS elevation and rotator values should be received at a nominal rate of 2 Hz, if this does not occur then error messages will be logged.

7.2.2.3 Starting the rotator tracking

To start rotator tracking the ROTTRACK must be set to 1 after the servo thread commences. In addition to indicating to the servo thread that it should commence issuing tracking demands to rotator's motor, this keyword also releases the brakes and enables (energizes) the motor.

The servo thread may terminate tracking upon detection of certain conditions (these are defined in Section 7.2.3 "Rotator servo behavior").

7.2.2.4 Stopping the rotator

To stop the rotator motor, including setting the brakes and disabling the motor, the ROTWOAH keyword must be set to 1. This keyword is not rothalt or rotstop due to an idiosyncrasy in the NIRC2 keyword library. A future modification is to allow rothalt and rotstop as analogous keywords.

7.2.2.5 Slewing the rotator to an arbitrary absolute position

To slew the rotator the ROTSLEW keyword is set to the desired angular position in degrees. This will disable tracking, slew the rotator to the desired position, disable the motor, and set the brakes.

Even though the rotator is effectively halted at some location, the DCS elevation and rotator demands are still processed and extrapolated by the servo thread. However, the resulting tracking demands are not output to the rotator's motor. If the DCS demands terminate then the rotator servo will generate error messages.

7.2.3 Rotator servo behavior

The rotator servo algorithm is essentially that which was used to drive the telescope's facility rotators at 40 Hz in the pre-EPICS control system.

As alluded to in previous sections, the servo attempts to calculate a rotator position from the DCS elevation and rotator demands. The DCS generates those demands at a nominal rate of 2 Hz. The rotator control must handle the varying arrival times of the demands and the fact that the demands specify the positions for the times at which they were issued, that is, the information is historical when received by the rotator control task.

The DCS generates two time stamp keywords with exactly the same value. The elevation and rotator demands are expected to arrive after reception of the first time stamp and before the second. The intent being that missed or out-of-order data can be detected and rejected. This behavior is controllable via a keyword, which must be tied to `pedantic_cb()` within `monitor_callbacks.c` (recall that the association of keywords to callbacks is done in `watch_nirc2_keywords.config`). Said behavior is not enabled by default.

Provision has also been made for the elevation and rotator demands to be bracketed by their own pair of time stamp records. This behavior is not enabled by default as DCS provides a single pair of time stamps. To change the default, one would need to associate the keyword `ROTONETS` with `rotParam_cb()` and set the keyword to 0. One would change the default behavior if the AO rotator generate demands were used rather than the DCS demands, for instance.

As each elevation and rotator demand is received, the information is stored then, when an event occurs on the second time stamp keyword, a Lagrange interpolating quadratic is fitted to the data (elevation and rotator independently via `update_rotation_info()` and `calc_extrap_coeffs()`) to a depth of three samples. The result is a set of coefficients for the equation `Cn-2 + Tn * (Cn-1 + Tn * Cn)`. Each time the servo thread awakens (at a nominal rate of 4 Hz) the Tn is set to the current time, as given by the network time protocol (NTP), in order to extrapolate a rotator tracking demand (via `extrapolate_posn()`).

Various conditions are detected, which may or may not cause the extrapolation information to be reset. Some of these conditions are detected when the information is updated when the DCS demands arrive (via `update_rotation_info()`) and some conditions are detected when the servo thread performs the extrapolation (via `extrapolate_posn()`). When a reset condition occurs the current extrapolation coefficients are used for another three updates, hence the servo thread will not respond to the condition for approximately 1.5 seconds. In addition, if the DCS demands terminate, the servo thread will continue extrapolating for another 3 minutes (this time is controllable with `ROTPSNTOUT` as discussed in Section 7.2.1 "Configuration").

Aside from checking the incoming DCS demands for timing (discussed above) the data is also checked: to ensure the times are monotonic; to ensure that the difference between the current demand and the expected demand – as calculated using the extrapolation routine – does not exceed some threshold (controllable via `ROTMAXSTEP`) above which a step impulse is assumed; and the demands are checked to determine if they are identical, which would imply that the rotator is to be stationary. Any of these conditions would cause an extrapolation reset and, in most cases, a temporary switch to slewing speed.

The extrapolation routine detects late data conditions. If the times between the DCS demands exceed a threshold, which is controllable via `ROTPSNLATE`, then an error message will be generated. As previously stated, there is an upper limit to the time, beyond which tracking will be terminated.

Aside from the conditions detected in the extrapolation routine, the servo thread also detects a few conditions.

Every servo cycle, a velocity is calculated for the two most recent extrapolated positions. If the velocity exceeds 1.0 degrees/second, then a velocity demand is output to the motor controller. The velocity is changed from 4000 counts/second to 150000 counts/second. The tracking velocity is output after a few seconds. This behavior is not ideal as, by default, the servo does not check the motor's current position, hence, there is no check that the motor is close to the desired position when switching back to tracking velocity. The reason for this is that the act of obtaining motor feedback actually takes so long that a servo cycle is often lost. Consequently, when a switch to slewing velocity occurs, a calculation is made to determine approximately how many servo cycles to allow for slewing.

The servo thread also determines if the tracking demand exceeds a software limit. When this occurs the demand is clamped at the software limit and an error message is generated.

If motor position sampling is enabled then the current position is examined to determine if the position exceeds a software limit. When this condition occurs the motor is halted and tracking is terminated. Also, while tracking, if the current position differs from the demand by more than two degrees a warning message is logged to inform the users that tracking is poor.

8 User Scripts

Users of the NIRC2 instrument would typically use integrated commands that are provided by a graphical user interface and/or UNIX shell scripts.

9 Animatics Motor Controllers

The NIRC2 instrument uses Animatics Smartmotors, which have an integrated motor, controller, controller interface, brake, incremental encoder, provisions for travel limit and homing switches, and an 8K-memory module. All the motors are equipped with the memory modules and switches, except the shutter assembly that does not have any switches.

The communications interface provides the RS-485 serial protocol. The RS-485 protocol allows connecting multiple motors on the same serial link in a star configuration. This is done for 10 of the 11 instrument motors, the pupil mask rotator motor being the exception as it is connected to a separate port.

On NIRC2, the motors are ultimately connected to terminal server ports that do not provide the RS-485 serial protocol; consequently, a DGH RS-232 to RS-485 converter box is connected between the terminal server ports and the motor controllers.

The Animatics motor controllers provide a rich command language. One should review the "*Animatics SmartMotor User's Manual*" for details in regard to the individual commands. The commands are all

ASCII strings consisting of printable characters except for the motor addresses. The motor addresses typically prefix a command and adding the integer value of the motor number to 0x80 generates them. The users need never concern themselves with this detail as the functions in `animatics.c` handle the motor address formatting, however, the programmer who intends to modify or implement new communications software must be aware of the requirements.

The version of the motor controllers used on NIRC2, as of November 2000, does not provide for buffering of incoming data – no FIFO on the UART – and they poll for the data. This is a limitation because the controller can miss data when running a subroutine (refer to Section 9 "Animatics Motor Controllers"), especially if conditional statements are used in the subroutine. The communication software and motor-controller subroutines were implemented so as to alleviate this problem as much as possible.

9.1 Animatics motor programs

The Animatics motor controllers are all equipped with memory modules. These modules are used to hold a set of subroutines that provide for motor initialization, homing, motion to absolute positions, and motion to relative positions.

A motor initialization subroutine is necessary as after a software reset or power cycle the motor dynamics are set to defaults which do not allow the mechanisms to move. The initialization subroutine sets the motor dynamics to safe values that allow the mechanisms to move but not necessarily at their optimums.

There are currently eleven different motor programs, one for each motor. This has arisen because of idiosyncrasies of the loadmotor program (described in Section 9.1.1 "Downloading and uploading motor controller programs). The only major differences are that each motor address command (`SADDR`) is different and the camera and slit motor initialization subroutines have different current values (`AMPS` commands).

All the motors use the same set of controller subroutines except the shutter and the pupil mask rotator; the shutter does not have any travel limit or homing switches so its homing routine is unique; and the pupil mask rotator requires a "tracking mode." The controller program, which is the same in nine of the motors, will be referred to as the generic motor program and subroutines.

The generic motor subroutines for homing and moving must release brakes, enable motor power (servo on), perform necessary motor rotations, apply the brakes, and disable motor power. In addition the motion routines must perform a backlash removal move prior to setting the brakes.

The Animatics motor controller language provides for 10 variables that can be used in subroutines. The variables are specified by single letters (a-j). The controller variables are used in the controller programs downloaded into the NIRC2 motor controllers.

All the controller variables default to a value of 0 after a software reset or power-cycle; hence they can be used to indicate whether or not certain operations have occurred. In this respect: the "a" variable is

set to 1 within the initialization subroutine to indicate that initialization has occurred; and the "h" variable is set to 1 within the homing subroutine to indicate that homing has occurred.

The Animatics controller language does not provide a status that explicitly indicates that a motor is in an idle state (not moving). To this end the "g" variable is used within the subroutines. The motor daemon communications software sets the "g" variable to a value that specifies which subroutine to execute. All controller subroutines set the "g" variable to 0 as their last command. Thus, the communications software can poll the "g" variable to determine whether or not a motor controller is currently executing a subroutine, where a value of 0 indicates the motor is idle.

The other motor controller variables are used as follows: "b" is set to the backlash distance which has a default of 200 steps in the initialization subroutine; "c" is set to delay used for WAIT commands that occur after motion and before applying brakes to allow for servo settling; "d"is set to the absolute or relative position demand to simplify the backlash algorithm in the motion subroutines; "e" is set to the maximum allowed position error above which the motor will abort with a stall fault; "f" is set to the maximum allowed velocity; "i" is used as a final offset within the homing subroutine; and "j" is used as a temporary variable within the homing subroutine.

9.1.1 Downloading and uploading motor controller programs

The Animatics motor control language provides commands for downloading and uploading motor-control programs into the controllers' memory modules. This is necessary to accommodate the NIRC2 mechanisms' motor requirements as described in the previous section. To facilitate these operations, a standalone program "`loadmotor`" was written, as partially described in Section 2.4.3 "Loadmotor." Problems have arisen with the `loadmotor` program due to idiosyncrasies within the terminal server, hence, motor memories are currently programmed via the "term" program, provided by Animatics, from a personal computer. The procedure for doing this is within the domain of the electronics group.

9.1.1.1 Loadmotor

The `loadmotor` program allows one to download a program into a motor controller and to upload a program from a motor controller. The motor can be connected to a host serial port or a terminal server port. A third mode was also implemented, which was intended to allow one to perform the programming operations via the motor daemon, however, as of November 2000, this mode has not been successfully debugged. If one simply types `loadmotor` on the instrument computer the correct command syntax will be displayed for the three modes.

Two problems exist with program control on the NIRC2 motor controllers:

First, one cannot successfully perform a programming operation when a motor is multi-dropped with other motors (recall that ten of the motors are multi-dropped), in fact, the programs in motors other than the one being addressed may be corrupted. Hence, one must connect a motor to a separate serial port (terminal server or host) prior to managing a motor's controller program.

The second problem is that the Animatics uses 0xff to mark the end of a motor controller program and that character cannot be successfully passed through the EMULEX terminal servers used on NIRC2.

As a result, one must cycle power to a motor controller after downloading a program into that controller. If this step is forgotten, the downloaded program will be corrupted and the download must be reattempted (after cycling power to the controller).

9.1.1.2 Animatics programming tool

10 DGH Devices (calibration lamps and cryogenic controls)

The NIRC2 calibration lamps and cryogenic controls all utilize DGH analog and digital I/O modules for control and status. The interface to these small modules is via RS-485 serial protocol. This permits multiple modules to be connected to a single serial link, as is done for the four modules in the cryogenic controls.

The connection from the NIRC2 host to the DGH modules involves two terminal server ports. As the terminal server ports do not function in RS-485 mode, there are two DGH RS-232 to RS-485 converter modules, between the DGH modules and the terminal server ports.

The NIRC2 instrument uses five DGH modules of three different types. A DGH 1712 digital I/O module is used for controlling the calibration lamps that are on a stage on the adaptive optics bench. Two DGH 1132 analog input modules and two DGH 4172 analog output modules are inside the cryogenic electronics.

Note that each analog output module has one analog output signal, one analog input signal, and three digital input signals. Each analog input module has one analog input signal, one digital input signal, and two digital output signals. Some of the extra signals are used; to determine how they are used one should review the cryogenic electronics documentation and the `nirc2_config_file`.

The dgh.c module is linked into the I/O daemon to provide configuration file parsing and communication routines.

11 Lakeshore Devices (temperature control and monitoring)

The NIRC2 temperature control and monitoring is performed with Lakeshore devices. The interface to the Lakeshore units is via RS-232 serial protocol, however, the serial port setup of the temperature controller is different from the temperature monitor's setup. As the units are connected to terminal server ports, the different serial characteristics are handled by appropriate configuration of those ports.

The Lakeshore units provide a rich command language in which all the commands consist of printable ASCII character strings. Only a few of the commands are required to support the NIRC2 keywords. If one needs to use an unsupported command, they must use `askdevice` as described in Section 3.4.1 "Askdevice."

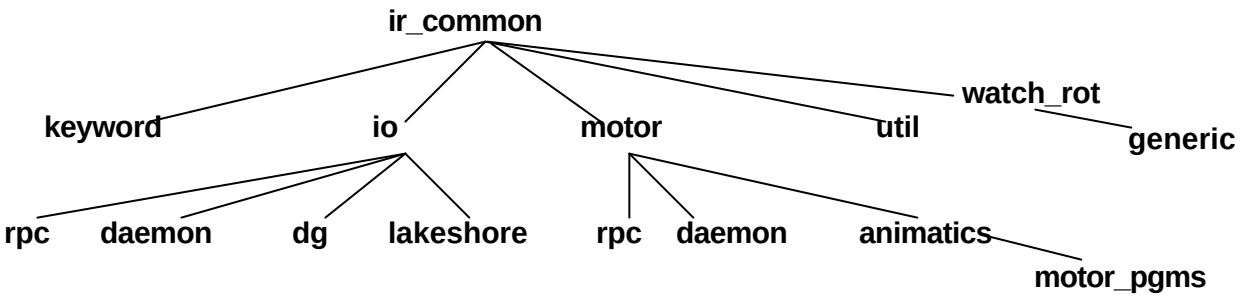
The lakeshore.c module is linked into the I/O daemon to provide configuration file parsing and communication routines.

12 Source Directories

The entire NIRC2 instrument software resides in numerous subdirectories, if one includes all the facility software such as the Keck Tasking Library and the Keck User Interface. However, NIRC2 programmers generally need only concern themselves with the source that is either unique to NIRC2 and/or was developed within the auspices of the instrument. This being so there are two sub trees that need to be understood /kroot/kss/nirc2 (mechanism-specific modules) and /kroot/kss/ir_common (low-level keyword interface and the daemons).

12.1 /kroot/kss/ir_common

The ir_common directory contains five subdirectories: util, which contains code that is used in the other subdirectories; keyword, which contains functions that support low-level motor and device keywords as well as the keyword event mechanism; motor, which comprises the motor daemon; io, which comprises the I/O daemon; and watch_rot, which is the heart of the pupil mask rotation servo control. Ultimately, the ir_common code will be used on other infrared instruments (NIRC and LWS as a minimum), hence, the reason it is not part of the /kroot/kss/nirc2 tree.



The files in ir_common/keyword implement the keyword interface to the remote devices. In addition, the modules of the form …Keyword.c can be linked into a minimal keyword library which would allow one to manipulate keywords associated with the remote devices so as to provide control and status of those devices. The intent is that one could build a bare-bones keyword library that would use the motor daemon and I/O daemon to communicate with instruments' motors and I/O devices in a few hours, prior to implementing the higher-level mechanism interface to the instrument.

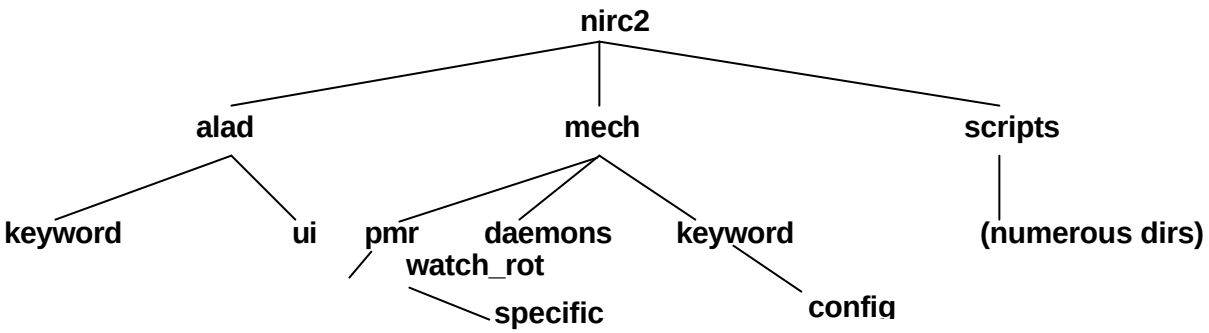
The ir_common/io is a sub tree, which forms the I/O daemon. There are two subdirectories, rpc and daemon, which form the interface to the daemon and the remote device communication functions. The remaining subdirectories (dgh and lakeshore for NIRC2) contain the communication interface for specific I/O devices. The files in ir_common/io itself consist of the keyword library interface to the I/O daemon (they translate keyword operations into the associated RPC calls) as well as standalone support programs (refer to Section 3.4 "Support programs"), which bypass the keyword library and interface directly to the I/O daemon.

The ir_common/motor is a sub tree, which forms the motor daemon. There are two subdirectories, rpc and daemon, which form the interface to the daemon and the motor-controller communication functions. The remaining subdirectories (just animatics for NIRC2) contain the communication interface for specific motor controllers. The files in ir_common/motor itself consist of the keyword library interface to the motor daemon (they translate keyword operations into the associated RPC calls) as well as standalone support programs (refer to section 2.4 "Support programs"), which bypass the keyword library and interface directly to the motor daemon.

The files in util supply miscellaneous functions used in the other subdirectories. The utilities include the errlog() implementation and an abstraction to the UNIX hash table facility, which is used for user variables (refer to Section 4.4 "User keywords").

12.2 /kroot/kss/nirc2

The nirc2 directory contains three main subdirectories: alad, which is the UCLA detector control and image processing software; mech, which is the instrument's high-level mechanism control and status software; and scripts, which are mostly shell scripts that comprise the instrument command set. The alad sub tree is not described herein as a separate set of documents exists for that purpose.



The scripts sub tree contains several subdirectores, which are more or less self-explanatory. This is the domain of the instrument specialists. There are other documents describing the command set supplied by the script sub tree.

The mech sub tree provides the mechanism-level keyword library functions that are described throughout this document, but specifically so in Section 4.1 "Mechanism keywords." The daemons subdirectory exists to tailor the motor and I/O daemons for NIRC2 and, consequently, consists of simply a `Makefile`. The pmr sub tree contains the implementation for the pupil mask rotator control (refer to Section 7 "Pupil Mask Rotator").